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THE SELECTION OF A METHOD OF CARTOGRAPHIC TERRAIN REPRESENTATION FOR USE ON THE 1:250,000 SCALE GENERAL PURPOSE MAP

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled The Selection of a Method of Cartographic Terrain Representation for Use on the 1:250,000 Scale General Purpose Map, submitted by William Silas Salter in partial fulfilment of the requirements for the degree of Master of Arts.

ABSTRACT

The primary problem to be solved, in the selection of a method of terrain representation for use on the 1:250,000 scale general purpose map, is that of evaluation. A technique of cartographic representation or symbolization should be an effective means of communication of facts and ideas. Cartographic method should be applied to that end. The content of the map should be determined as a function of the purposes of the map. The technique of representation used must impart information useful for those purposes.

A study of the methods of cartographic terrain description was carried out. The technique may be generally classified into three categories: the morphometric (quantitative methods), the morphologic and the morphographic (qualitative methods). Some means of representation are useful for descriptions of limited aspects of the terrain. Others can be used to provide a broad description. The technique of pictorial representation developed by A. H. Robinson and N. J. W. Thrower was selected as being suitable for use on the 1:250,000 scale general purpose map. The method was used to map an area in southwestern Alberta. The area mapped exhibits a varying relief which includes extensive plains, hills and mountain sections. The map provides an effective and useful description of the

terrain of this area. The representation is visually evocative of the landform and the information presented is useful for a wide range of purposes.

ACKNOWLEDGMENTS

The writer would like to express his appreciation to Professor J. J. Klawe for the aid and encouragement given during the preparation of this study, to Mr. Jack Chesterman who competently reproduced many of the illustrations, and to Mrs. Jean Clarke who typed the thesis.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Numerous techniques of symbolization and representation have been developed to portray the terrain cartographically. The variety of methods is a reflection of the complexity of the subject. The cartographer is rarely required to treat so broad a topic as a unity. The mapping of climate, for example, frequently involves the preparation of several maps of the climatic elements of temperature, precipitation, pressure, winds, etc. Economic subjects are normally classified into a range of topics to be treated separately. Elements of surface form can be, and often are, treated thematically in the same manner by the cartographer. There also exists a strong demand for maps upon which the various aspects of the terrain are summarized, providing a general statement on the configuration of the surface. It is in this area that many of the problems of terrain representation arise.

In this study the writer examines some of the problems associated with design and selection of a method of terrain representation for use on the 1:250,000 general purpose map. The criteria used in the selection of the method are based upon an examination of the function of the 1:250,000 scale map and the application of cartographic method. The survey of several aspects of cartographic method contained in Chapter I is intended to disclose some of the problems which must be solved in

order to produce a functional and effective map of the terrain. Consideration is given to the function of the 1:250,000 map, and to the aims of cartographic method. The evaluation of the methods of terrain representation which are discussed in Chapter II is based upon those two considerations.

The selection of the method is discussed in Chapter III. It is not the intent of the writer to make any judgement on the utility of the techniques discussed for purposes other than their employment on the 1:250,000 general purpose map. The type of information mapped and the means of symbolization varies according to the technique. A method which functions poorly at a particular scale or for a specified purpose may be useful under different circumstances. The methods are examined in order to select a technique which is most useful for the specified purposes discussed in this study.

A discussion of the application of the method chosen is contained in Chapter IV. The conditions under which the experimental map was prepared permitted only an approximate reproduction of a standard topographic sheet. The map is monochromatic and it is felt that a clearer more effective definition of detail could have been produced with the use of colour. The construction of the symbolization was carried out with the aid of 1:50,000 scale topographic sheets. A preliminary general survey of the physiography and geology of the map area

was carried out. This was intended as an aid in the selection of detail for emphasis and as a guide to the evaluation of the accuracy of the pictorial image.

Although the study is limited in scope it is intended as a contribution to the assessment of techniques at the disposal of the cartographer and an aid towards their more effective use.

CHAPTER I

CARTOGRAPHIC METHOD AND MAP FUNCTION

The compilation and design of a map for a particular purpose must be based on an awareness of the uses to which that map will be put. The function of the map must be taken into account in the choice of scale and projection, the selection of data, and the manner of symbolization, where these factors affect the content of the map.

The cartographic method, the sequence of action from conception to finished product is essentially the same for the preparation of all maps, and has been developed to meet the requirements of the general function of maps. The map functions as a form of communication and as an image of some surface phenomena, presenting data spatially organized in two, or three, dimensions for visual inspection.

An evaluation of any cartographic technique must be based on these two considerations; the adequacy of the technique as it is used in the solution of a particular mapping problem, and the effectiveness of the method as an aid to communication.

The Evaluation of Maps

Robinson,[1] in a discussion of cartographic

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[1] A. H. Robinson, The Look of Maps, An Examination of Cartographic Design, Madison, 1952, p. 22.

method suggests that the subject may be divided into three categories, substantive method, visual method and reproduction. This classification is of use in examining the problem of evaluation. Substantive method relates to the analysis of data, including both quantitative and qualitative aspects. The "appropriateness" and accuracy of data are considered to be quantitative problems. The categorization, generalization, and the determination of class limits and ratios for data are qualitative problems. The aims of substantive method are to select and prepare the data for mapping. Visual method includes the design and use of symbolization, the preparation of the graphic form or vehicle for the presentation of information. The problem of reproduction is peripheral to this study.

Map content is the information which can be extracted from the map. The map reader can assign certain qualitative and quantitative values to map symbols. In many ways the understanding of statistically derived qualities of extent, character, or size which can be obtained from the map is similar to that which is formed from an examination of the data in its original form. The values obtained from the map are normally less exact. However, a basic assumption of mapping is that through the use of the means of cartographic presentation, the original data can be qualified and made more comprehensible in some ways. A contour

map produced from a list of spot heights with their geographic locations has a greater descriptive value than the tabulation of the data. The determination of map content is the primary problem of substantive method.

The evaluation of content can be based upon an estimation of its appropriateness and accuracy. Such an evaluation in those terms is based upon an understanding of the requirements of the map user and the uses of the map.

The effectiveness of the map as a communication form and as an image of the distribution of phenomena depends upon the visual techniques employed. Principles of design, applied to the construction and selection of symbolization form the basis of visual method. The cartographer must utilize his graphic techniques to facilitate the understanding of the subject mapped. The extent to which the visual method achieves this objective is the basis for its evaluation.

The Application of Cartographic Method

Cartographic method may be described as the means whereby the cartographer constructs a map, including the employment of scale, projection, generalization, symbolization and the solution of problems attendant upon their employment. It is convenient to recognize four steps in this approach. They are: the selection and generalization of data, the preparation of the base map, the design and application of symbolization, and reproduction. This is a simplification of procedure,

intended only as a basis for discussion of problems related to cartographic method.

The objective of the cartographic treatment of a subject is to reproduce at a reduced scale an image of the distribution and occurrence of some phenomena. "The map's basic contribution is to reduce reality to a scale which can be comprehended."[2] The map functions as an image and a record of some distribution. The employment of a projection and the use of scale reduction enables the cartographer to preserve certain aspects of the spatial relationships existing on the globe. Resulting distortion is measurable, as are distances between points on the map. The selection and location of data on the map provides an additional correlation between the map and that part of the Earth's surface it represents. The manner in which the data is portrayed reflects the terrestrial distribution of that data. Cartographic method is employed to produce an image which retains both qualitative and quantitative relationships. Just as the preparation of the base map and the deployment of data are critical to the maintenance of the substantive aspects of the subject, so the symbolization is used to qualify the subject and communicate the information to the reader.

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[2] E. L. Ullman, "Human Geography and Area Research", A.A.A.G., Vol. 43, 1953, p. 218.

Projection and Scale

The choice of scale and projection determines the charateristics of the structural framework of the map. The projection used governs the shape and qualities of the matrix upon which locations are established. The scale provides a means of measurement and is a concise expression of the amount of reduction.

The scale of the map is the ratio of distances measured in units on the map to distances measured in the same units on the ground. The representative fraction also implies varying degrees of compression and generalization. The detail, emphasis, and accuracy in the representation of phenomena will vary accordingly. The scale must be chosen to suit the purposes of the map. Generally, the smaller the scale, the larger the area which can be mapped on a sheet of convenient size. Maps prepared for use in engineering studies where detailed information of a small area is required, employ scales of 1:2,500 and larger. Aeronautical charts must be of a far smaller scale, from 1:250,000 to 1:1,000,000. Although information on the form of the terrain is required in both cases, the depth of presentation must vary considerably. The nature of information obtained from a map using a technique of symbolization at one scale will often be different from the information obtained where a similar technique is employed at another scale. The selection of symbolization must be judged

accordingly. It is not advisable to attempt to evaluate the worth of a particular method of terrain representation without considering its application at various scales and purposes

The consideration of projection in this study is limited. The aim of the employment of any projection is to systematically transfer location of points from the Earth's surface, a sphere, to the map, a plane. Where the area to be mapped represents a small fraction of the Earth's surface, curvature exercises slight influence on this process. Topographic sheets at scales of 1:250,000 and larger may be treated as being conformal for most purposes. The graticule is not, however, an exact duplication of the relationships existing on the ellipsoid. The desireable characteristics of projections used for topographic maps are, that the projection error should be nowhere great enough to cause serious distortion, and that the error be of such a nature that its magnitude and kind can be easily calculated for any part of the map, and therefore allowed for in accurate measurements made off the map.[3] The orthomorphic projections satisfy these requirements and, on the Canadian topographical series, projection error can be disregarded for most uses.

Smaller scale maps of larger area cannot utilize

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[3] J. A. Steers, An Introduction to the Study of Map Projections, London, 1962, p. 228.

any projection in quite the same way. Where a large segment of the Earth's surface must be projected onto the map plane, all geometrical relationships on the ellipsoid of rotation cannot be duplicated. The cartographer selects a projection which retains those characteristics of geometry and design most useful to the purposes of the map.

The use of projections illustrates a principle of cartographic method which also applies to other areas of technique. The image presented on the map is a partial and limited one. As in the choice of a projection which emphasizes several properties at the expense of others, all phenomena shown on the map are emphasized or repressed in the same way. The manner in which this is accomplished, and the concepts of generalization and symbolization, employing selection and emphasis are central to this study.

Selection and Generalization of Data

All maps are images, reduced in scale. Generalization is a necessary accompaniment of this reduction. It is not possible to reproduce all characteristics and detail of a particular subject on the map. "Every map drawing by its very nature is a generalization of the area it represents."[4] The purposes of generalization

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[4] E. Imhof, "Tasks and Methods of Theoretical Cartography", International Yearbook of Cartography, 1963, p. 14.

and selection of data are to clarify and emphasize the characteristics of the phenomena mapped. The effects of reduction of aerial photographs has been noted by Robinson. Crowding of information of varying orders of importance occurs, intricacies are increased in proportion to the ratio of reduction, legibility in general is reduced. The problems of the cartographer are similar.

The cartographer must generalize both the content and the symbolization of the map. Generalization in content is accomplished through the elimination of unimportant information, by the classification of data, by the assignment of prominence to particular features, and by the analysis of data for particular patterns. This procedure belongs to the aspect of cartographic method termed "intellectual generalization" by Robinson.[5] The generalization of information through the use of symbols and the generalization of symbols has been termed "visual generalization".

Intellectual generalization is the generalization of information or data. This is accomplished through the careful elimination of items shown at a larger scale, or on the Earth's surface so that the character of the phenomena and of the distribution of kinds of phenomena

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[5] Robinson, <u>op. cit.</u>, p. 12 ff.

are retained at a smaller scale. The result is loss of detail which may be compensated for in part through an adjustment in the design of symbolization. The amount and type of generalization is a function of both scale and the purposes of the map. A more generalized representation of phenomena than the scale reduction dictates may be a desireable attribute of a map designed for particular uses.

The elimination of kinds of phenomena, the categorizing of data into classes, the representation fo one or of only a few elements, the selection of a representative sample of items, and the substitution of one or more aspects of a phenomena for the mapping of the whole are techniques of intellectual generalization in the selection of data. In their discussion of one aspect of intellectual generalization Jenks and Coulson make the following analogy to visual generalization:

> Dividing data into classes for statistical maps can be compared to generalization of coast lines on small scale maps. Details of the original data are obscured by the process and the map-reader gains his impression of the distribution from whatever pattern is formed by the class intervals that have been selected.[6]

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[6] George F. Jenks and Michael R. C. Coulson, "Class Intervals for Statistical Maps", International Yearbook of Cartography, 1963, p. 119.

The selection of data is the choice of information to be used to illustrate particular phenomena cartographically, as for example the use of census figures to show population distribution, or land heights to describe the land surface form. This choice is related to all considerations of generalization as well as other factors. The cartographer is required to select and generalize the data in varying degrees. Where he is presented with a problem explicitly stated as to the data to be used, the problems of generalization and presentation are limited to the visual aspects. Where the problem is presented in more general terms, the cartographer must find the limits imposed by the intended function of the map and the data available. In this second case, several considerations must be taken into account; the subject of the map, the availability of data, the reliability of the data, the map scale and the amount of detail required.

An example from the compilation of the Atlas of Alberta, illustrates the manner in which the subject of the map may pose problems in the selection and use of data. The production of a map or a number of maps on the topic "standard of living" was intended. This is a broad topic open to several interpretations. The production of the maps required the selection of several different sets of data on such diverse topics as size of dwelling, appliance ownership, rents, automobile

ownership and types of dwellings, which would function as indices of the standard of living. The method of approach illustrates an important cartographic principle pertaining to the selection of data. That is, that data on a particular subject may be used to indicate variation of a greater phenomena of which the subject data selected is a part. The components may be mapped individually or a statistical index may be prepared and mapped. This latter approach is well illustrated in the Atlas of Economic Development.[7] In both cases the principle is essentially the same.

The cartographer is often restricted in his choice of data by that which is available. In such cases he may be required to substitute less effective elements to illustrate a subject. When the data is available but unreliable or incomplete, the subject may be mapped without detail, and the method of symbolization will be affected. The lack of quantitative information can in some cases be compensated for, partially in the design of symbolization. Where, for example, detailed contour information is lacking, form representation through shading or some other means can be used to indicate the general trends of the land surface.

The map scale and the amount of detail required

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[7] N. Ginsburg (ed.), Atlas of Economic Development, Chicago, 1961.

are interrelated considerations upon which the type and extent of processing of data depends. These factors are determined in part by the purpose of the map and in part by the techniques of symbolization which can be used.

Symbolization of Data

All information on the map is presented by means of symbolization. Just as the map is a symbolic image of a part of the Earth's surface, so it is composed of symbols representing lesser phenomena. The two most important considerations for the design and application of symbolization are: the effectiveness of the symbols for representing the data and functioning as a concise statement of information, and the type and extent of visual qualification given that information. The cartographer must be aware of the effects of variations in the choice of letter styles, point, line and area symbols, and colours. He must consider also, the relationships of symbols on the map.

The aim of cartographic design is to present a legible, effective portrayal of the subject mapped. The response of the reader to information presented on the map will be based on both intellectual and visual perception. The quantitative nature of the data and their spatial relationships are retained by assigning values to the symbols, identifying them with the infoma-tion so presented, and locating the data symbols on the map. The visual qualification of information which

automatically attends its cartographic display is ideally designed to re-enforce the reader's understanding of the map.

The cartographer has at his disposal a wide array of media and techniques. The possible ways in which a given set of data can be mapped are infinite. Only through the application of sound principles of design can the cartographer achieve the communication objectives of the map.

> Every map is a complex stimulus, for all its shapes have both visual and intellectual relationships to one another. Anything existing within the neat or trim lines may be described as a series of related intellectual concepts represented by visual media. In some cases the visual symbolism is so characteristic or well known that one is able, unconsciously to disregard the visual stimuli and see and recognize clearly the intellectual concept. In other cases the medium acts more like a cleverly constructed mask and so obscures the intellectual thought that the only way to determine its identity is through reference to a legend or a key.[8]

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[8] Robinson, _op. cit._, pp. 8 - 9.

The reaction of the map reader to the cartographic display of information is similar in type to the reaction of the viewer to a photograph. The objects so portrayed may be recognized but the way in which they is presented may cause a reaction based upon the visual aspects of the presentation.

> With visual perception, we see not what exists, but what we think exists, and memory and imagination are quick to fill in any gaps. We depend so much on the use of our eyes that we tend to regard them as infallible, even though perception is what the organism experiences, not what the physical world contains.[9]

The order of viewing is such that the map reader first looks at the map, and makes a preliminary judgement based on visual stimuli. Reference to the legend and more careful examination follows. If the initial visual reaction conflicts with the results of the more intensive examination, the intellectual intent of the map will be obscured and the map reader may have difficulty in understanding the information presented. It is likewise possible for the graphic symbolization to be so inadequate for the purpose, or so complex, that no visual pattern is readily perceivable. In such cases the map is not

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[9] J. S. Keates, "The Perception of Colour in Cartography", Cartographic Symposium, Edinburgh, 1962, p. 19.

performing any visual function except perhaps to confound.

The cartographer must avoid the transmission of false information visually just as strongly as he avoids the use of inaccurate or false data. The examination of the data, its distribution, relative quantitative importance, and the qualitative differences, the intent of the map, the patterns to be shown, and the intellectual concept involved are all considerations to be borne in mind in the design of symbolization.

The purpose of visual symbolization is to reenforce cartographically the content of data to be mapped. Robinson[10] has suggested several characteristics desireable in symbols, including: economy of expression, suitability of the character of symbols, precision, contrast, and the ability to evoke an identification of the symbol with the phenomena it represents.

The first of these, economy of expression, is the requirement that the symbol be designed as simply as possible. An economical form can be easily recognized and a comparison of the characteristics of such symbols is more easily accomplished. Contrast is a related characteristic. It is the purpose of the map to facilitate the perception of differences where they exist, symbols which contrast graphically with the background are more easily seen, and symbols which indicate quantitative differences visually and readily are desireable.

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[10] A. H. Robinson, op. cit.,

Evocative symbols are those which more easily identify visually the phenomena they represent, thereby presenting a less abstract and more easily comprehensible image to the map reader. The use of evocative symbols at small scales can be designed to overcome some of the statistical generalizations which may be necessary.

Philbrick[11] has presented several principles useful in the employment of cartographic method. In these he emphasizes several points which are of value in the description of the cartographic approach and in the application of technique. The cartographer must select those elements of the landscape which are of importance to the purpose of the map. By the same criterion he assigns statistical and qualitative value to particular phenomena. The order of importance of items shown must be judged and graphically represented accordingly. The differences should be shown but always in proportion. The means of symbolization should be suggestive of the patterns, subject and values assigned.

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[11] A. K. Philbrick, "Towards a Unity of Cartographical Forms and Geographical Content", Prof. Geogr, Vol. V, No. 5, 1953, pp. 11 - 13.

CHAPTER II

METHODS OF CARTOGRAPHIC TERRAIN REPRESENTATION

The aim of cartographic terrain representation on the 1:250,000 scale map is to provide a reasonably objective description of the surface configuration. To accomplish this end the cartographer must select an approach from a wide range of methods. The extent of the reduction from actual size to cartographic scale requires that the subject be generalized. The cartographer can retain only a limited range of the characteristics and detail of the subject. A map is, therefore, more suggestive of the terrain than descriptive. The subject to be mapped must be broken down into its component parts. Those elements which can be used to construct the best possible symbolic representation for the purpose of the map must be selected. Elements of the terrain which are utilized as a basis for cartographic terrain representation include: metrics of slope, elevation, and extent; landform categories based on quantitative measure or geneiric interpretation; shape; surficial and bedrock geology; and the texture or pattern of the terrain formed by the association of features. Techniques of symbolization vary from the abstract to the highly evocative. All methods of cartographic terrain representation were not designed to function at the same scales nor for the same purposes. They do contain elements of interest which are of use in

the design of symbolization for the 1:250,000 scale general purpose map.

The treatment of the techniques of terrain representation which follows is intended to fulfill two functions. The first purpose is to assist in the selection of the method most suitable for use on the 1:250,000 map. The second object is to provide an illustration of the manner in which the selection of elements and symbolization operate to provide varying and occasionally contrasting views of the same subject.

Some difficulty was experienced in classifying the methods of terrain description for discussion. Three categories are used. The morphometric techniques are those which indicate the areal distribution of measured values of particular terrain elements, most frequently slope and elevation. These methods are characterized by the emphasis which is placed on the substantive aspects of the terrain description rather than the graphic means of portrayal. The morphologic approach includes those methods which are based on generic interpretation and classification of land-forms, physiographic maps for example. Morphographic description is based upon the qualitative, evocative portrayal of shape, for example relief shading. Particular emphasis is given to the symbolization of the terrain.

Morphometric Methods of Terrain Description

Morphometric methods of terrain description have been designed for maps ranging from the largest to the smallest scales. They vary in complexity from simple spot heights to involved indices of slope, elevation and distribution. The main attraction of the morphometric approach lies in the promotion of these methods as being more objective and consistent in application than other techniques. Just as the numerical term is often more concise than the verbal, so the quantitative expression is often considered to be more precise than the qualitative. If this were the case, the morphometric techniques would have certain clear advantages over other means. Apart from precision and economy, both of which are desireable characteristics, the more objective and consistent treatment would allow further interpretation without prejudicing the results.

Spot heights consist of no more than the location of established elevations on the map using point numerical symbols. For large areas of northern Canada covered by older maps, these provide the only direct clue to the surface form on the 1:250,000 topographic maps. Used alone, a limited number of spot heights can allow only the most generalized estimate of gross variation in the elevation of surface form. Their value lies primarily in their suitability for use with other methods of description to provide additional information.

A contour is an isarithm of equal elevation above a datum plane. The contour is one of the most versatile techniques used for indicating variations in surface configuration. The original method of determining the location of the contour line was by interpolation using a network of established deviations. Such a process necessarily required a large element of subjective interpretation. The use of air photography for establishing contours has since allowed a greater accuracy in their positioning. Other difficulties both in the use and drawing of contours, remain. Among these are; the selection of the vertical interval to be used, the generalization of contours from larger to smaller scale maps, and the use of contours for the portrayal of surface shapes.

Landforms of small extent and minor local relief are often important both in the determination of the character of the terrain and in a wide range of areal studies. At the largest mapping scales a small vertical interval may be employed which will permit these features to be shown. At a scale of 1:250,000, the interval must be larger for most areas in order to prevent the visual confusion resulting from a dense cover of contour lines. Where the interval ranges from one hundred to five hundred feet, as on the 1:250,000 Canadian topographic maps, features of considerable local relief may be omitted or imperfectly shown. Where a feature of low local relief is positioned about

the interval elevation it may be shown. Larger features positioned vertically between intervals would be omitted. Such a case is illustrated in figure one. The difficulty lies not in the accuracy of the contour, but in its use to show surface form. The map reader may attach exaggerated importance to features delineated by the contours, while the impression obtained from examining areas where there are few contours may be entirely false.

A. J. Pannekock, in a discussion of the generalization of contours suggests that the main object of relief representation on maps has been to represent the character of the slope and the form of the land rather than the elevation of each point.[1] At smaller scales contours have been used for this purpose even though they are not usually suitable. Relief consists of intersecting slopes, each of which is characterized by the direction, distance, divergence or convergence of the contours. At a large scale, contours in an area of low relief are so far apart that they cannot be measured with certainty to determine the angle of actual slopes. With the decrease in scale from 1:50,000 to 1:250,000 only the largest slopes can be distinguished and the commensurability of the contours delimiting these is doubtful.

Pannekock states that even with careful generalization the distinguishing characteristics of

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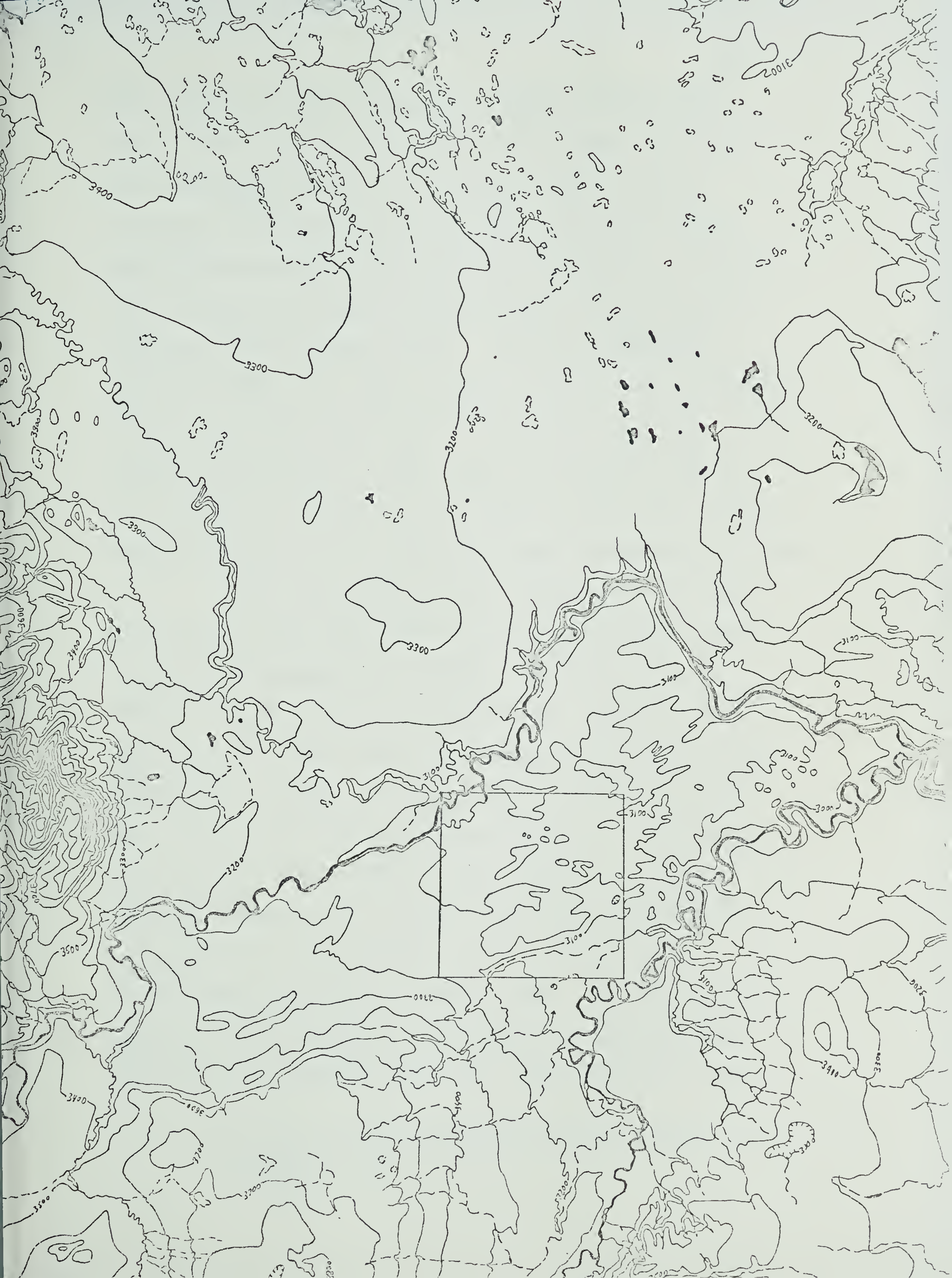
[1] A. J. Pannekock, "Generalization of Coastlines and Contours", International Yearbook of Cartography, 1962, p. 61.

FIGURE I THE EFFECT OF CONTOURS AS USED AT SCALES OF 1:50,000 AND 1:250,000
EXCERPTS FROM CANADIAN TOPOGRAPHIC MAPS 82 H 11/W AND 82 H

The contours of an area are shown as mapped at scales of 1:50,000 (above) and 1:250,000 (right). The vertical intervals are 25 ft. and 100 ft. Minor variations in relief near 3,100 ft. in elevation are mapped at both scales, i.e. A, B, C. The terrain of the area is generally level, the most prominent feat-being the east trending valley in the south. In the excerpt from the 1:250,000 map, the minor forms (relief 10-20 ft.) are given the same emphasis as the valley and ridge. The map reader is liable to interpret the terrain as being more irregular than is actually the case.

The 1:250,000 scale excerpt is shown in context overleaf.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many types of relief disappear. Those relief types based on the tectonic structure, for example plateau-like topography based on horizontal beds, or fold topography can still be recognized. However, relief types determined by lithology such as limestone or sandstone topography cannot be generalized because they influence the detailed relief. Glacial topography cannot be shown at a small scale because of the character of the associated landforms.[2] Contours, even when properly generalized, cannot give an accurate idea of slope, area of surface at particular elevations or small relief features, at any but the larger topographic scales.

The recognition of the inadequacies of small scale contour maps has led to the development of other quantitative descriptive methods. Elevation is, in itself, a poor index of configuration. Local relief, and values of slope have been emphasized in these other techniques. A number of small scale terrain maps have been produced utilizing numerical values of elevation, local relief, mean slopes, modal slopes, or indices based on combinations of these and their distribution vertically and horizontally. Such information is derived from large scale contour maps. The aim of this approach is to provide a statistical or quantitative description of surface features. The aspects of land

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[2] Ibid, p. 66.

form used are those amenable to quantification which are considered to be most characteristic of the variation in surface form.

One advantage of this approach lies in the consistency of application which is possible. Direct comparisons can be more easily made between the areas mapped because the application of the procedure can be standardized. The terms of such a comparison can be, however, only those of the method applied. Nor can many statistical methods of description be applied with equal effectiveness to all types of terrain. The problems of application of this approach lie partially in the utility of the parameters used and partially in the need for subjective judgment at critical points.

Guy-Harold Smith used a method of empirical description based on local relief for the preparation of a relative relief map of Ohio.[3] The elements of surface form considered in his study include; altitude above sea level or some other datum, degree and direction of slope, local relief, texture, and pattern of the terrain. Local relief was used because the values obtained provide some indication of the areas in different slope categories. This was based on the assumption that the area in steeper slope categories will be greater in an area of high local relief.[4] The method used required the division of the

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[3] Guy-Harold Smith, "The Relative Relief of Ohio", Geogr, Rev., Vol. 25, 1935, pp. 272 - 284.

[4] Ibid, p. 273.

base map into regular shaped areal units measuring five minutes of latitude by five minutes of longitude. Within each unit of this grid the difference in elevation between the highest and lowest points was calculated. This relative-relief value was plotted at the centre of each grid section. Isopleths of one hundred foot vertical intervals were drawn from these relief values. The resultant map was intended as a "quantitative statement on the irregularities of the terrain".[5]

Wentworth's method of determining average slope is a good example of the morphometric approach to the mapping of this element of land form.[6] The method is based upon the calculation of the tangent of the mean angle of declivity within a particular area. The average slope value is obtained by using the formula $SM = \frac{IN}{K}$ where I is the vertical interval of the contours, N is the number of intersects along a grid section, and K is a constant. A grid of units measuring one mile square was placed on a contour map and the number of contour intersects along each mile counted. Where the contours intersect the grid line at angles other than ninety degrees, the result from the tangent formula, $\tan. = \frac{\text{rise in slope}}{\text{horizontal distance}}$ will be less than the true value. To compensate for this, an average angle of

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[5] Ibid, p. 277.

[6] C. K. Wentworth, "A Simplified Method of Determining the Average Slope of Land Surfaces", American Journal of Science, Series 5, Vol. 20, 1930, pp. 184 - 194.

intersect is used. The resultant constant, K, is equal to the sine of this average angle of intersect, multiplied by 5,280. The values were calculated along horizontal and the vertical lines of the grid using the average slope formula. The grid was rotated forty-five degrees and the procedure repeated. An average of the four values obtained for each section of the grid was calculated. This was the average slope value used.

There are many variations on these two basic methods of statistical terrain description, employing such devices as modal slope values,[7] and the frequency distribution of slope steepness with respect to area. The categorizing of this information for mapping may be of two main types. The first is the establishment of interval classes in order to apply isopleth or choropleth symbology. The second requires the identification of landform categories, or landscape classes, based upon the employment of several descriptive devices. Guy-Harold Smith's map of Ohio falls into the first class, the landform maps developed by Hammond are of the second type.

Hammond's landform maps were designed for use at small scales.[8] In his discussion Hammond treats the

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[7] M. Bullock, A Landform Map of Southern Alberta, unpublished M. A. thesis, University of Alberta, 1966.

[8] E. H. Hammond, "Small Scale Continental Landform Maps", A.A.A.G., Vol. 44, 1954, pp. 33 - 42.

problem of the use of methods particularily suitable for large scales for atlas sized maps. The resulting generalization of the terrain symbolization is such that little valuable information can be obtained. By emphasizing the characteristics which define certain classes of terrain types it is possible to empirically categorize surface features. The classes may be delineated and mapped. The emphasis of this type of description is placed upon the content and definition of limits of the terrain categories. The symbolization serves primarily as a device for the portrayal of areal distribution of local relief values, slope values (expressed as the per cent of the unit area having a slope of less than eight per cent), and profile (a function of the vertical distribution of near level land).

The impetus for the development of methods of statistical terrain description derives from the desire for a more useful and objective portrayal of surface form at smaller scales. The mapping of readily employable numerical values of significant land form characteristics compensates for the lack of commensurability of other methods. The use of these indices is a form of generalization. The range of information, compared to that which can be shown at topographic scales, is reduced, but the detail of some characteristics is retained.

Calef and Newcomb have examined some of the problems connected with the statistical approach to

terrain description.[9] All slope or relief maps require the diversion of the range of slope conditions that occur into slope or relief interval classes. These may be arrived at by at least three methods. The first is the arbitrary selection of class limits in advance. The second is to subdivide the base map into areas of differing average slopes based on an inspection of topographic maps. The slope class limits can be selected to show as many of these areas as possible. The third approach requires the selection of the limits so that those terrain types which are considered to be of greatest importance can be shown.

The class interval selected will determine the size and shape of areas in different categories on the map. Calef and Newcomb conclude that maps of average slope are highly subjective.

The sources of the subjective element are:

1) the arbitrary nature of the selection of slope categories,
2) the determinating effect of the selected slope categories on the delimiting of areas of contrasting slope conditions, and
3) the necessity of arbitrary decisions in the delineation of slope boundaries in all

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[9] W. Calef and R. Newcomb, "An Average Slope Map of Illinois", A.A.A.G., Vol. 43, 1953, pp. 305 - 316.

> areas of gradual transition from one slope category to another or in areas of complex associations of varying terrain types.[10]

Although these criticisms arise from a study of the application of average slope methods, the same criticism may be applied to all maps of this type which require the categorization of information into different classes. The authors also cast doubt upon the value of such maps as descriptive devices, concluding that they are more useful as statistical research tools. The statistical descriptive maps of the terrain function not as general purpose maps but rather as thematic portrayals of particular surface characteristics.

Morphologic Methods of Terrain Description

Morphologic maps are those which portray the terrain in terms of landforms classified according to structure or genesis. These maps are intended as small or medium scale descriptions of the surface. The best known of this type are the pictorial maps produced by Raisz and Lobeck. Raisz describes the function of his pictorial landform maps as the provision of "information about the ruggedness, trend, and character of mountains, ridges, plains, plateaus, canyons, and so on -- in a word the physiography of the region".[11] Robinson in a discussion of

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[10] Ibid., pp. 307 ff.

[11] E. J. Raisz, "The Physiographic Method of Representing Scenery on Maps", Geogr. Rev., Vol. 21, 1931, pp. 297 - 304.

a physiographic diagram of Korea[12] describes it as an aid in the description of the gross geomorphology of the area.

The terrain is divided into physiographic units. The extent of this subdivision varies. The system described by Raisz in 1931 utilizes forty categories based upon structure, surficial deposits, form, origin and age.[13] An additional ten subdivisions of the plains category are given based on vegetation and climate. Of particular interest to this study is the technique of symbolization. Each category is mapped with standardized pictorial symbols, evocative of the landform. Such symbols rarely represent an individual feature, but rather, indicate the occurrence of a landform type which is the domin nt characteristic of the landscape. Although the terminology, and method of classification has been questioned, the maps illustrate a useful method of generalization for small scale representations. The landform categories and their general characteristics are familiar to the reader who has a minimal aquaintance with physiography. Both the terminology and the symbolization are evocative of a particular association of surface features thereby contributing to the success of this method.

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[12] A. H. Robinson and S. McCune, "Physiographic Diagram of Tyosen (Korea)", Geogr. Rev., Vol. 31, 1941, pp. 654 - 658.

[13] Raisz, loc. cit.

FIGURE 2 AN EXCERPT FROM ERWIN RAISZ, LANDFORMS OF THE NORTHWESTERN STATES, SCALE 1:1,350,000, 1941

THE FIGURE ILLUSTRATES THE USE OF MORPHOLOGIC PICTORIAL TERRAIN REPRESENTATION.

Morphographic Methods of Terrain Representation

Morphographic techniques are those which employ graphic symbols to evoke, visually, the form of the earth's surface. Less emphasis is placed upon the ordering of terrain elements, their logical categorization and classification for presentation as indicators of terrain conditions. More stress is placed upon the use of the elements of landform for the construction of descriptive symbols. The devices included in this category range from supplementary visual symbols designed for application with other methods of terrain representation to those which are intended as complete techniques of terrain portrayal. Form shading, hachures, pictorial perspective symbolization, illuminated contours, and orthogonal methods are all intended for use in the provision of a graphically descriptive image of surface form.

The intensity of light reflected from an uneven surface varies according to the angle and direction of slopes relative to the direction of the source of illumination. Several techniques, including form shading and hachuring are designed to utilize the visual aspects of this phenomenon for the portrayal of surface form.

The hachure is a line symbol drawn down the slope and varied in width according to the angle of the slope represented. By assigning a range of values to

the hachures, the intent is to give the symbol quantitative meaning. The overall effect of variation in light and dark is intended to provide a qualitative description of surface form. There are several methods of applying hachures.

Lehman's method of hachuring presumes a zenithal light source over all parts of the terrain. Light reflected back in the direction of origin would vary with the angle of slope of the reflecting surface. The steepest slopes would appear as the darkest areas. The lightest areas would be those of little or no slope. The variation of light and dark is symbolized using hachure lines of varying width or density. In the Lehman system the width of the hachures is varied according to the angle of slope.[14] A more realistic portrayal can be achieved by darkening shadowed slopes as with an oblique source of illumination. Figures three and four illustrate the two different approaches.

Robinson summarizes some of the disadvantages of hachuring technique.[15] The visual effect of the hachured representation is achieved through the use of thousands of tiny line symbols. The hachures are varied in number and character over the map to produce a mosaic of light and dark areas. The visual effect is analogous to that produced by a greatly enlarged screened photograph.

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[14] A. H. Robinson, Elements of Cartography, 2nd edition, New York, 1960, pp. 202 - 203.

[15] Ibid.

FIGURE 3 AN EXCERPT FROM <u>EGER</u>, 30° 50°, SCALE 1:200,000, MAP PUBLISHED BY THE GOVERNMENT OF GERMANY 1939

HACHURES ARE USED TO DESCRIBE THE TERRAIN. A ZENITHAL SOURCE OF ILLUMINATION IS PRESUMED.

Variations in the width of the hachures can be detected but it is difficult to assign absolute values to them. The symbols are too small and the variations in width too slight for easy visual comparison. When the vertical illumination has been used there may be some difficulty in separating valley bottoms from hill tops. The hachures provide a poor background for the display of other information. The introduction of photographic screening has allowed the development of improved means of representing surface form. The hachuring technique remains of interest in that, unlike form shading, the symbolization may be applied in a reasonably objective systematic manner. The method of application precludes the introduction of a subjective element in the selection of tone values for individual slopes. The image of the terrain configuration obtained by the reader from maps of different areas to which the same hachuring technique has been applied is more directly comparable than that which could be obtained where continuous tone shading is employed.

Form shading is the representation of surface form by means of variations in application of light and shade. This effect can be produced by photographing an illuminated model of the area or by graphically constructing a representation of the hypothetical effect of such a process. The amount of light reflected from a surface will vary according to its composition, cover, angle of slope and orientation of surface facets relative to the

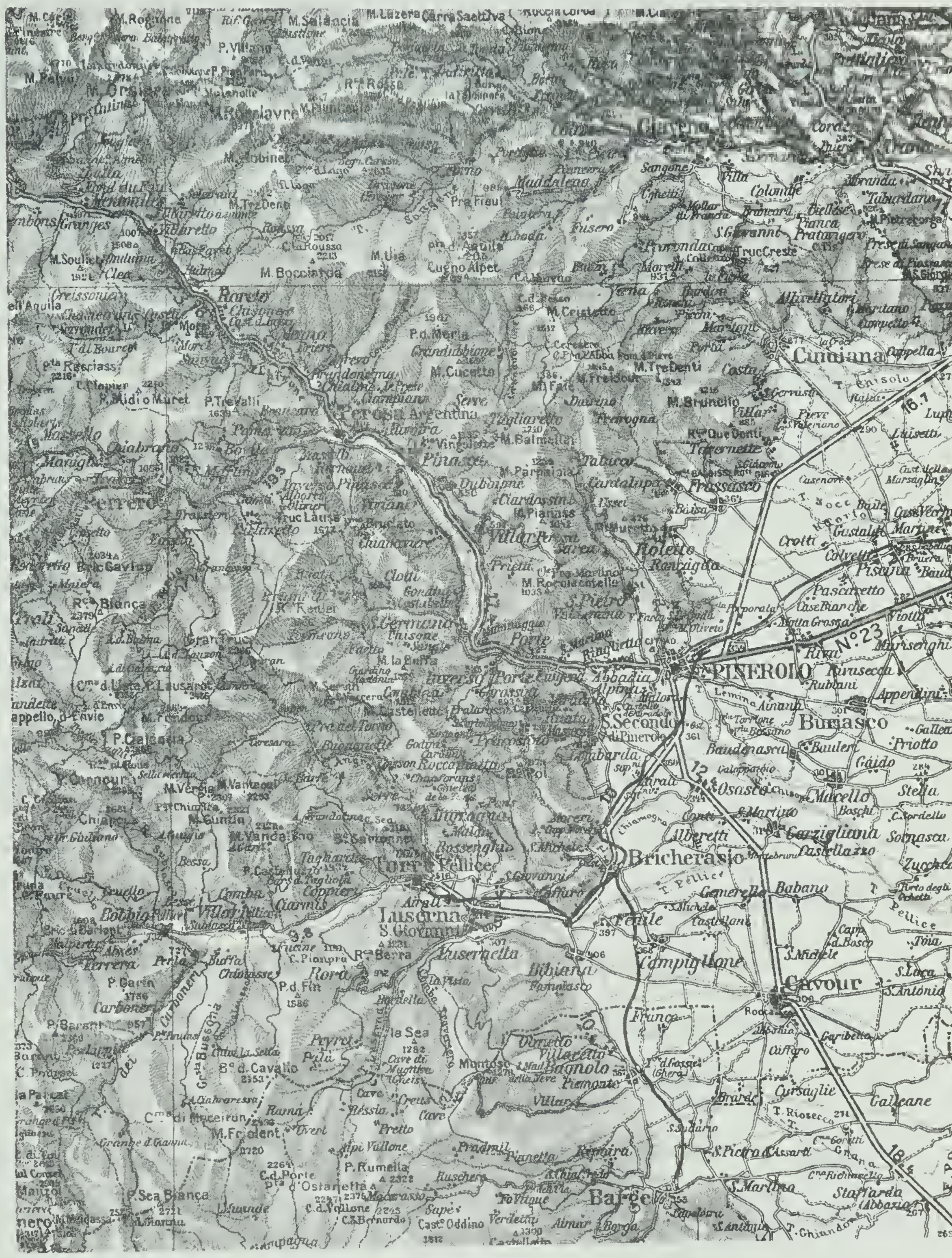

FIGURE 4 AN EXCERPT FROM <u>SUSA</u>, CARTA D'ITALIA DEL TOURING CLUB ITALIANO, FOGLIO 8, SCALE 1:250,000, 1949

THE FIGURE ILLUSTRATES AN APPLICATION OF HACHURES TO PORTRAY OBLIQUELY ILLUMINATED TERRAIN.

source of illumination. Techniques of form shading are based on consideration of the latter two factors.

There is no unanimity as to which of the two approaches photographic or graphic, has greater merit. The photographic method requires the production of a model of the relief. This is a disadvantage. The shading produced by photographic means can be more consistent and presumably more objective. The drawing of form shading requires a degree of subjective judgment and interpretation which may result in inconsistency. In the opinion of the writer, this approach also allows a greater flexibility and freedom to emphasize certain features and to define shapes with more clarity.

Unlike hachures, the shading is not applied according to a systematically defined relationship between angle of slope and the direction of the light source. The density of shading applied is determined qualitatively by the cartographer on the basis of several considerations. These include: the direction of the hypothetical light source and the angle of illumination, the orientation and steepness of slopes, the height of surface features, the relative importance of features, and the degree of generalization desired.

Although vertical illumination may be used, oblique lighting is most common. The oblique allows for the representation of slopes as belonging to two general categories; those which are shadowed, and those which are lighted. The oblique lighting permits the

creation of a strong three dimensional effect, based in part on the contrast between the light and dark of opposing slopes. The technique is similar in this respect to the utilization of shadow by the artist to show volume. Terrain illuminated from the lower right of the point of view may appear reversed, or visually confused, for this reason the oblique light source is usually assumed to be to the upper left of the map.

In the strict application of principle those slopes which are most nearly perpendicular to the angle and direction of light would be represented as the brightest areas on the map. The principle cannot always be followed. It is occasionally necessary to shade facing slopes and illuminate "shadowed" slopes to bring out the form of certain features. Light and dark may also be applied as a function of height, the highest illuminated slopes being the brightest, and the highest shadowed slopes, the darkest.

The successful use of form shading depends in large measure upon the ability of the cartographer to utilize lighter and darker tones to construct recognizable images of surface forms. Where contour maps are available for the area, they may be utilized as guidelines for the location of various shades, the estimation of slope angle and direction, and the evaluation of form. A more accurate image of form and of the interplay of light and shade which characterize particular shapes, can be ensured by referring to air photographs of the area.

Where the cartographer relies solely upon contours, the generalizations and omissions of these will be reflected in the final result. Large scale contour maps do provide sufficient information to serve satisfactorally as guides for the drawing of form shading at smaller scales.

Although many techniques useful for the mapping of surface form are available, these are often ignored and the contour is used. Contours can be used effectively as a guide for the interpretation of surface shapes on large scale maps. The utility of the contour for this purpose depends upon the vertical interval used and the extent of generalization. At scales of 1:50,000 and greater the contour interval used is a useful guide to the minimum size of surface forms which can be interpreted in this manner. At a scale of 1:250,000 generalization is so extensive that the contour should be used only as a indicator of elevation. Form shading can be used to indicate qualitatively the characteristic shapes at any scale. The detail of the representation varies with the scale. On atlas sized maps the smallest features shown are mountain ranges and major valleys. The gross features of the terrain can, however, still be shown and the landform rendering retains its strong visual effect. The techniques of form shading could be more frequently employed on the 1:250,000 Canadian topographic maps where at present the main technique of terrain representation used is the contour. Form

shading is a more useful technique for use in the general description of surface configuration.

Form shading has several important defects, inherent and in application. It is not commensurable. Although a qualitative assessment can be made of the relative steepness of slopes and of the elevation of features relative to each other, quantitative information must be provided by other means. Certain land form shapes cannot be easily shown. The visual effect is dependent upon the use of contrasts of light and dark. Sharp breaks in slope, steep slopes, and features of high local relief such as mountain peaks or incised river valleys can be well defined. Rounded shapes and gentle slopes of low relief which require gradations in tone or light tones, may be poorly defined and difficult to recognize. Slopes which are oriented along the direction of illumination cannot be as well defined as slopes which are perpendicular to the light source. Slopes facing the source of illumination will be characterized by the absence of shading, or light tones. The detail is, therefore, difficult to show. Generally the smaller features are more difficult to characterize than the larger. Because the application of shading is dependent upon individual judgment, similar features located in different parts of the map area may be portrayed differently. It is not possible to maintain a completely consistent approach. The problem becomes more acute in the production of a series of maps. An example of the

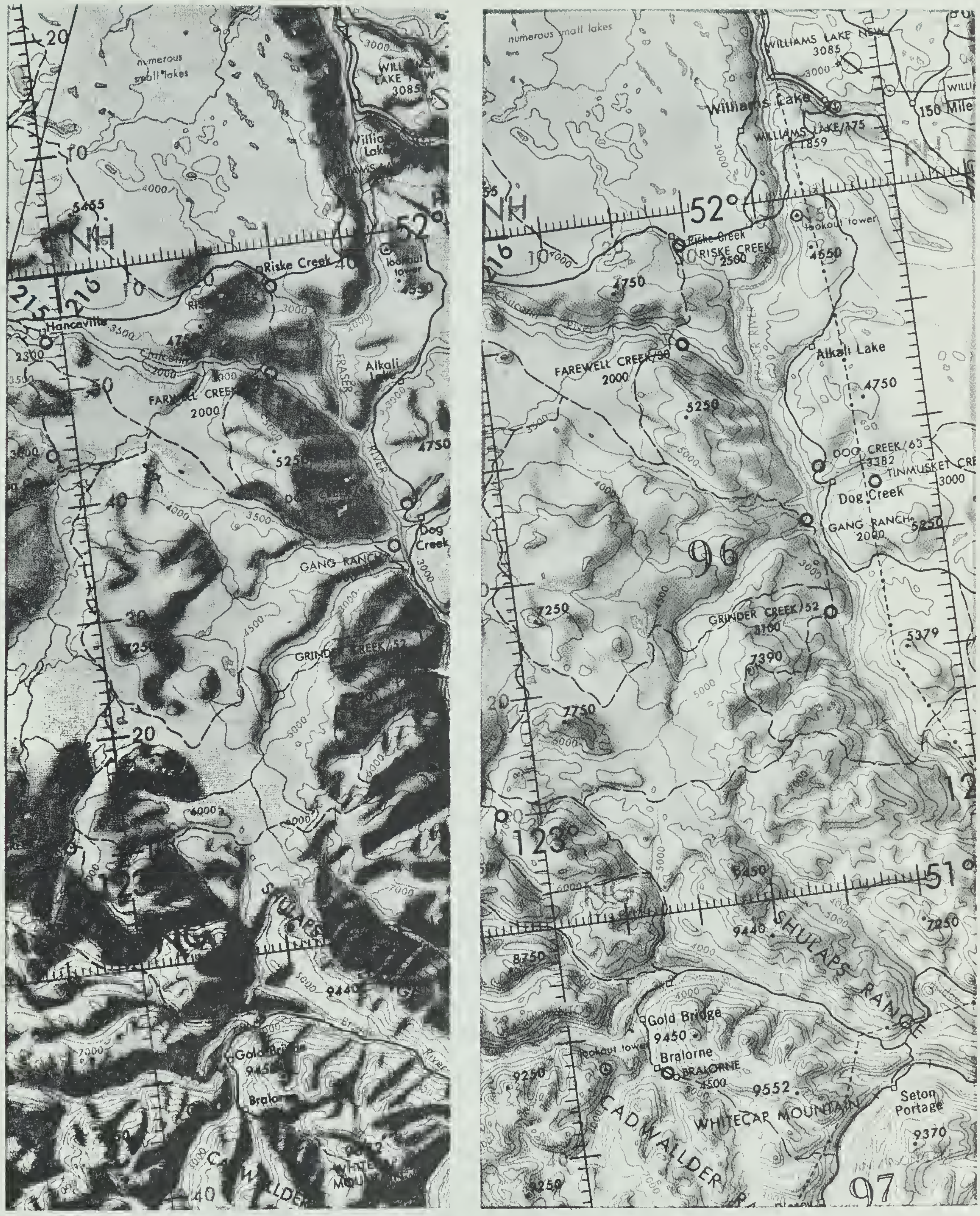

FIGURE 5 A COMPARISON OF THE FORM SHADING DRAWN ON TWO MAPS OF A SERIES

The map excerpts are from sheets E15 and E16, of the 1:1,000,000 scale, "Operational Navigation Charts" published by the United States Air Force, 1967. The section illustrated is from the area of overlapping coverage of the two charts. Not only is the shading darker on the western chart, probably a result of the use of a different ink and screen for reproduction, the detail of the terrain is also shaded differently.

inconsistency which can result is illustrated in Figure five.

Techniques of form shading are rarely used at larger scales without additional terrain symbolization. Rock drawing and conventional symbols can be used to provide clarification of the shapes. Contours and spot heights can be shown to add an element of commensurability. The best examples of this approach are the topographic maps produced by the Swiss. There are examples of large scale topographic maps upon which form shading is the only means of terrain description. An exerpt from one of a series of topographic maps produced by the British Directorate of Overseas Surveys for the Nigerian government is reproduced in Figure six. For this series the shading was drawn from photo mosaics to provide an effective terrain rendering for areas where precise survey information was lacking and maps were required quickly.

The problem of inconsistency in the application of form shading has been discussed by Kitiro Tanaka.[16] His "relief contour method" is intended as a means of controlling the appearance of brightness and darkness of different slopes according to a fixed standard. The method is not form shading but a substitute. This technique consists of the illumination of contours to enhance

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[16] Kitiro Tanaka, "The Relief Contour Method of Representing Topography on Maps", Geogr. Rev., Vol. 40, 1950, pp. 444 - 456.

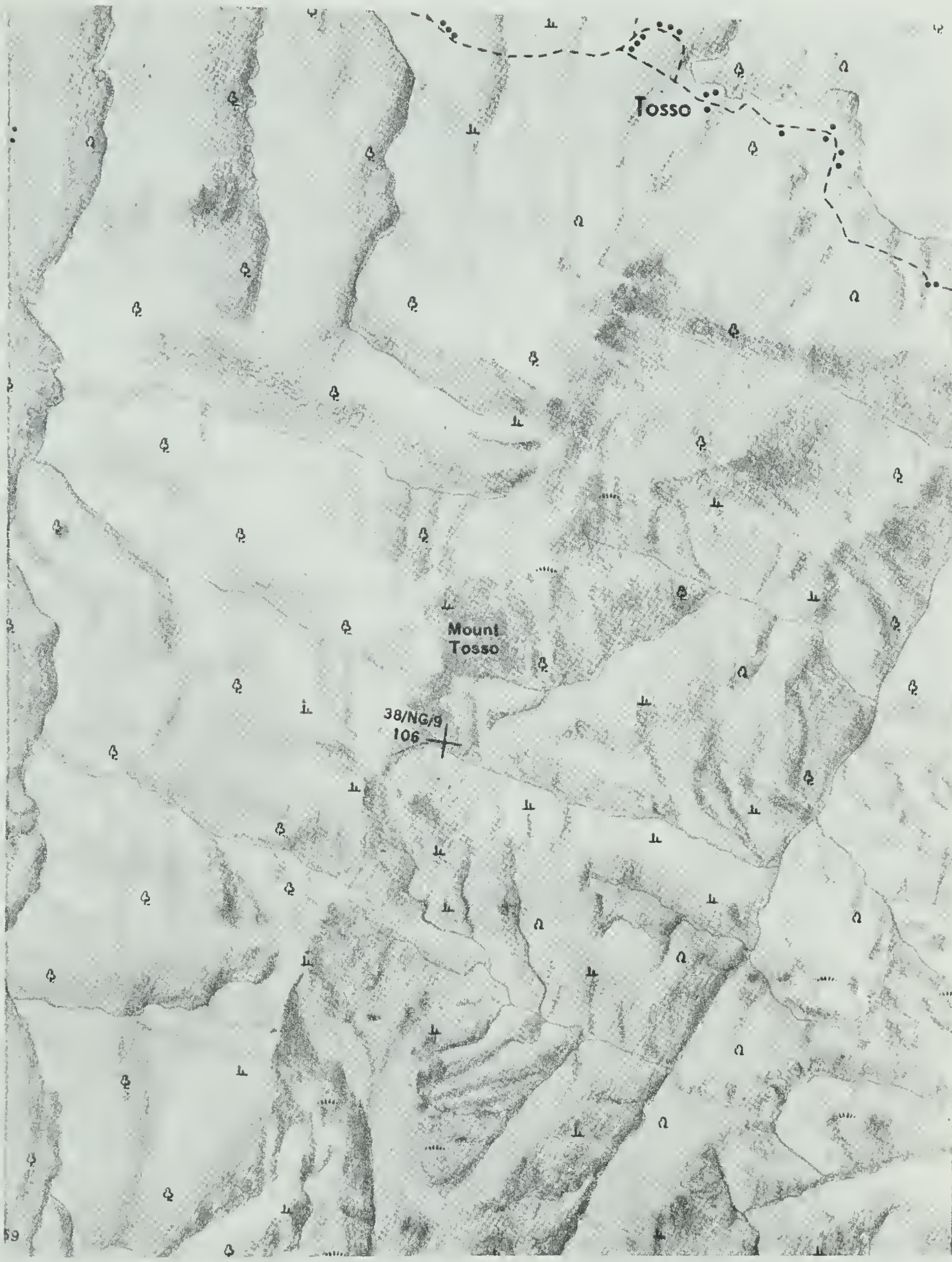

FIGURE 6 AN EXCERPT FROM ESU N.W., MAP SHEET 293 N.W., PUBLISHED BY THE DIRECTORATE OF OVERSEAS SURVEYS FOR THE NIGERIAN GOVERNMENT, 1963, SCALE 1:50,000
THE FIGURE ILLUSTRATES THE USE OF FORM SHADING AS THE SOLE MEANS OF TERRAIN DESCRIPTION

their utility for the description of form at larger scales. Contours are varied in thickness according to the angle at which they lie relative to the light source. Those contours which lie at an angle within ninety degrees of the direction of light are shown in white, those which face away from the illumination are portrayed in black. The background is shown in a neutral grey. Variations in tone are achieved by a visual merging of the contours of varying character on the map. Although a strong visual illusion of form shading can be created using this approach, there are several drawbacks. The method is subject to the same criticisms as are applied to the use of contours. At large scales where the contour density is highest the technique is most effective. Where contours are horizontally farther apart much of the plasticity is lost. At smaller scales where contours are less indicative of form, their emphasis by this means becomes pointless.

The hachure and the methods of form shading are attempts to portray the shape of the surface as seen from above (although the position of the landforms is orthographically represented). A second major class of morphographic techniques is based on the utilization of an oblique view of the terrain. These techniques range in complexity from the simple pictorial perspective symbols which are among the oldest means of terrain representation to the use of orthogonally projected traces of the inclined plane to draw an apparent profile

FIGURE 7 AN EXCERPT FROM U.S.GEOLOGICAL SURVEY, MOUNT MCKINLEY NATIONAL PARK, SCALE 1:250,000 , 1952
THE FIGURE ILLUSTRATES THE USE OF FORM SHADING WITH CONTOURS TO DESCRIBE THE TERRAIN.

of the surface.

The earliest portrayal of surface features may have been based on the representation of the simplified outline of hills or mountains. Such pictorial symbols are evocative of the features as viewed from the most familiar vantage point, eye level. The nature of this type of symbolization is such that surface forms can be recognized on the map by a range of map users who may be unfamiliar with cartographic techniques.

This approach has other advantages. The physiographic maps discussed earlier commonly utilize pictorial perspective symbolization. At small scales it is more difficult to indicate differences in the detail of shape using the alternative methods. The perspective view introduces the additional defining characteristic of profile. The use of a line drawing technique allows the inclusion of additional detail without cluttering the map. These two factors are important advantages to consider in the design of medium scale physiographic maps, where the need for differentiation among terrain types and their evocative presentation arises.

Oblique perspective methods permit the use of the technique of vertical exaggeration. One of the major difficulties of terrain representation involves the portrayal of features of both high and low relief on the same map. The height of most terrain features can be exaggerated without damaging the visual effect. Visual estimates of the height and slope of landforms

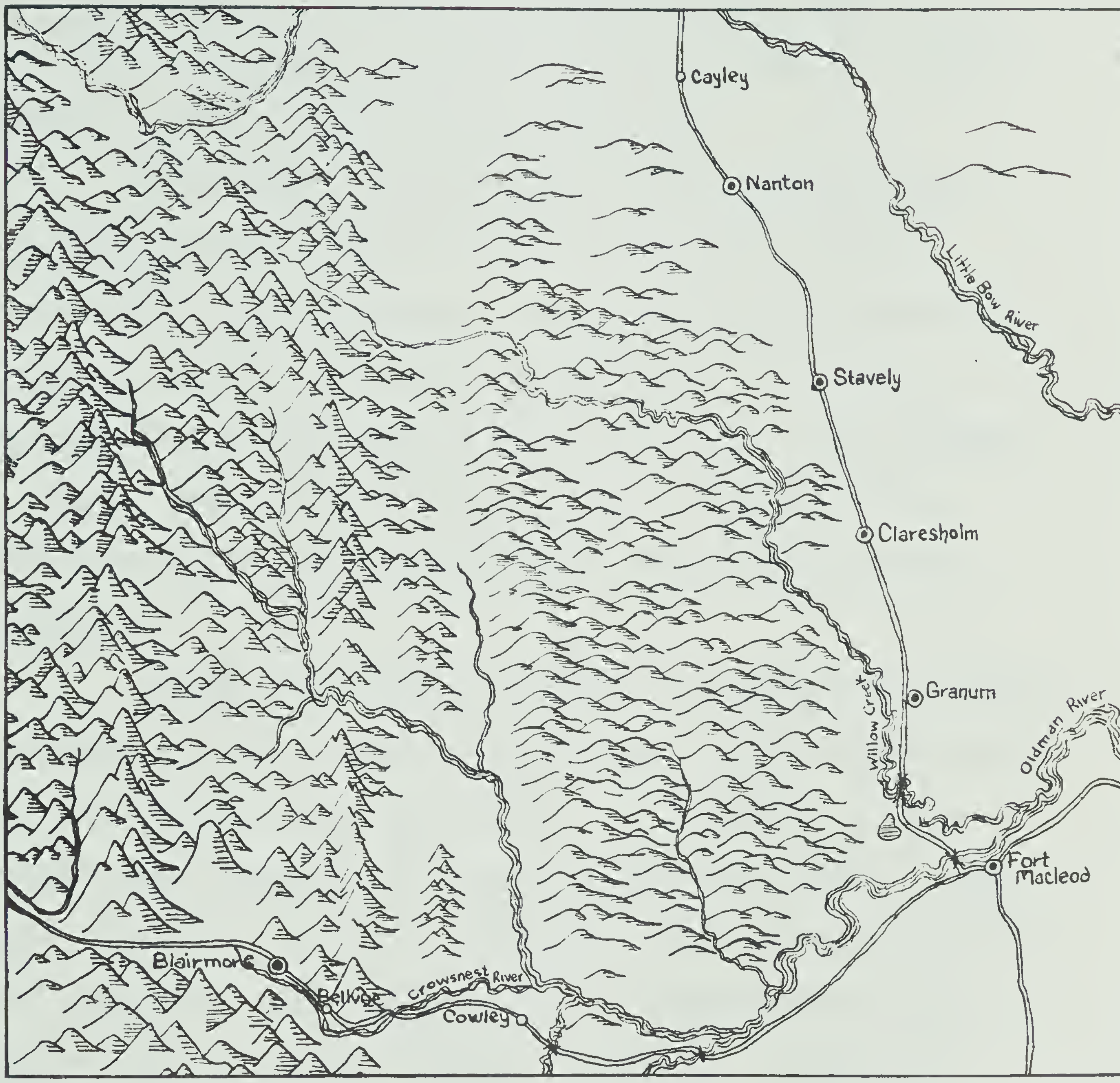

FIGURE 8 AN EARLY METHOD OF PICTORIAL TERRAIN REPRESENTATION THE FIGURE SHOWS A PART OF SOUTHWESTERN ALBERTA MAPPED IN A MANNER COMMONLY USED BEFORE THE INTRODUCTION OF HACHURING. SCALE 1:760,320

are usually greater than the measured values. The graphic exaggeration of relief may produce a pictorial representation which is closer to the reader's experience. It is possible, therefore, to utilize a vertical scale which is several times as large as the horizontal scale. By this means the height of smaller features can be exaggerated to facilitate their representation.

The graphic technique of line drawing allows for a more precise definition of detail than can be effected with form shading. Where shading is suggestive of volume, depth, and change by gradation, the line indicates the boundaries of form, direction, and changes in slope. The line drawing is a more flexible device for illustration of the individual characteristics of features.

Most conventional methods of perspective terrain portrayal are characterized by several disadvantages which limit their use at larger scales. The portrayal of a profile view requires the use of horizontal space on the map to show the vertical. This not only wastes space but also precludes the representation of backslopes, and smaller features behind larger landforms. Points are displaced from their true position according to their elevation or relief. The representation is often not commensurable, and only a limited range of quantitative information can be derived from those which are commensurable. The nature of the terrain representation is frequently such that it forms a background too dark

or too complex for the portrayal of other information. When pictorial representation is used, much of the generalization of the terrain is accomplished during the drawing of the map. Care must be taken that the treatment is consistent and that the interpretation is correct. The effectiveness of the portrayal and the accuracy of the map will depend upon the judgement exercised by the cartographer during the preparation of the representation.

Two techniques of perspective terrain representation which are relevant to medium scale maps are the proportional relief method of Ridd[17] and the inclined contour method of Robinson and Thrower.[18]

The proportional relief landform map described by Ridd is an adaptation to medium scale mapping of the pictorial techniques used for small scale physiographic maps. The object of his study was to produce a pictorial map of the terrain at a medium scale suitable for "state-sized" areas. Two major disadvantages of the perspective symbolization are discussed, the planimetric displacement of features, and the lack of commensurability. Displacement is reduced through the use of the "local base" concept. Local base is described as the locus of points around the foot of a mountain or some other feature where

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[17] M. K. Ridd, "The Proportional Relief Landform Map", A.A.A.G., Vol. 53, 1963, pp. 569 - 576.

[18] A. H. Robinson and N. J. W. Thrower, "A New Method of Terrain Representation", Geogr. Rev., Vol. 47, 1957, pp. 507 - 520.

the break in slope is sharpest. Because the elevation of this base may vary from place to place over the map area, the local base may be thought of as an undulating surface. The major streams, valleys and flats are not displaced and are therefore planimetrically correct. All peaks and other elevated points are displaced proportionally from their local base according to a predetermined scale. The amount of this displacement can be measured on the resultant map and the local relief determined. Individual features are drawn in profile in the conventional pictorial manner.

The inclined contour method of terrain representation was first put forward by Tanaka.[19] The object of his study was to determine the quantitative relationship between the angle of light incident to a surface and the amount of light reflected from that surface. This relationship was to be utilized as the basis for a method of terrain representation. Tanaka concluded that the brightness of any elementary surface of the ground is proportional to the cosine of the incident angle of the ray of light for that surface. The inclined contour was developed as a vehicle for the cartographic representation of this variation of brightness on an irregular surface.

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[19] Kitiro Tanaka, "Orthographical Relief Method of Representing Hill Features on a Topographical Map", Geogr. Jour., Vol. 79, 1932, pp. 213 - 219.

If a surface is cut at regular intervals by a series of closely spaced parallel inclined planes, the traces of the line of contact between the planes and the surface can be projected orthogonally onto the map. These traces are similar in appearance to profiles but are planimetrically correct. The traces, or inclined contours, were drawn in black and white on a neutral background. The sections of the traces representing illuminated slopes were drawn in white. Those facing away from the light source were drawn in black. The width of the lines are varied according to the angle of the inclined contour. Figure nine illustrates this procedure.

The effect is analogous to that produced by the strong oblique illumination of a relief model. The method is simple to apply and the representation is visually striking but the background formed by the terrain is too dark for the effective display of other information.

The pictorial technique developed by Robinson and Thrower[20] is based upon the use of the inclined contours as guidelines for the drawing of pictorial terrain representation. By using the planimetrically correct traces instead of profiles of the terrain several defects of the conventional pictorial maps can

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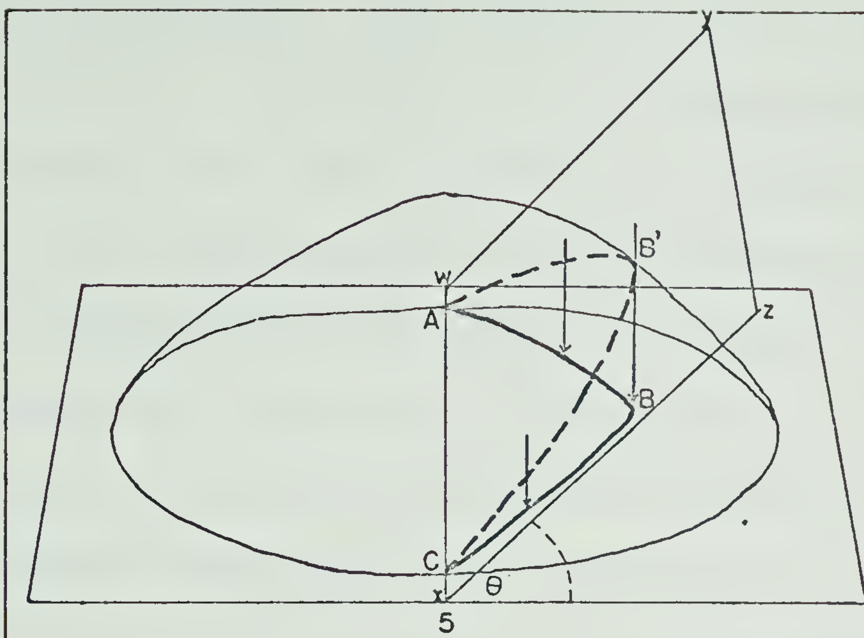
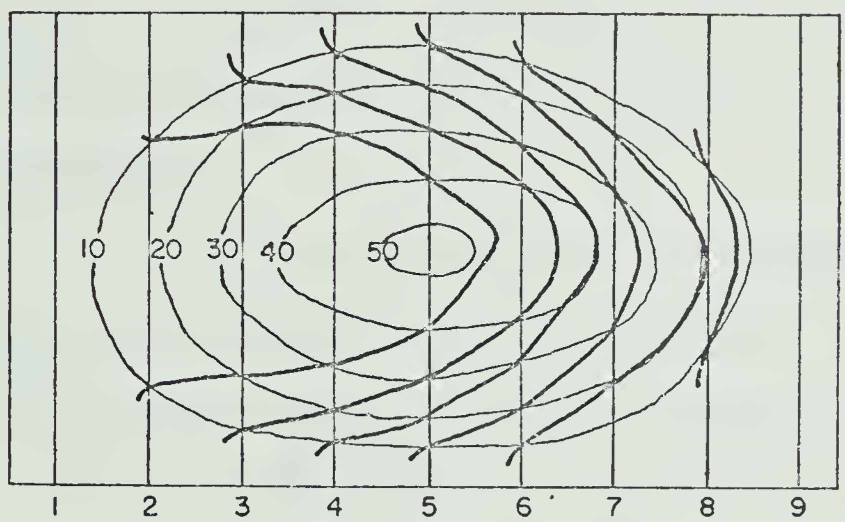
[20] Robinson and Thrower, loc. cit.

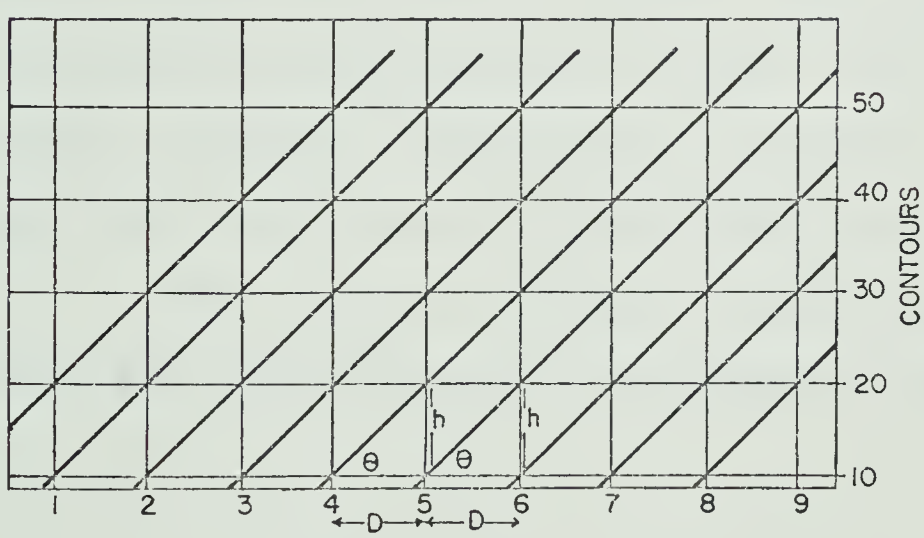


A B'C is the trace of an inclined plane, wxyz, passing through a land form at an angle, θ. ABC is the trace, projected orthogonally on to the map plane.



The lines numbered 1 to 9 represent the lines of contact between each of a series of inclined planes and suceeding contour elevations. The traces, sybolized by the heavy lines, are drawn in the manner described on pages 66 and 67 in the text.

The lines, 1 to 9, would normally be constructed horizontally. The orientation has been changed for purposes of illustration.



The relationship between the contour interval, h, the angle of inclination, θ, and the spacing of the lines, D, is diagramed at left. The heavy lines represent the vertical crossections of the inclined planes.

$$D = \frac{12\, h \;\cot\theta}{\text{scale denominator}}$$

FIGURE 9 THE CONSTRUCTION OF ORTHOGONAL TRACES OF THE INCLINED PLANE
After A.H. Robinson and N.J.W. Thrower, "A New Method of Terrain Representation", <u>Geog Rev.</u>, Vol. 47, 1957, pp. 507-520.

be eliminated. The features can be shown in their true position, backslopes can be represented, and smaller features are not eliminated by the need for displacement of the larger shapes. The technique is quite different in effect from the original proposal of Tanaka. The traces are drawn at an intermediate stage of construction as an aid for the pictorial terrain rendering. Variations in light and shade are represented by the density of traces and interpolated lines between the traces on the slopes. The method is discussed in more detail in the succeeding chapters of this study.

Conclusion

Several techniques of terrain representation have been omitted from this survey. There are many variations on the approaches outlined here. Methods may be used in combinations as spot heights, contours and form shading often are, or alone. There are several techniques of symbolization intended for use with other methods. Noteable among these are the use of hypsometric tints with contours, and rock drawing with form shading.

The utility of several of the techniques for use on the 1:250,000 map is discussed in the next chapter.

CHAPTER III

A METHOD OF TERRAIN REPRESENTATION FOR USE ON THE 1:250,000 SCALE MAP

The accompanying map, figure nineteen illustrates a technique of terrain representation which is, in the opinion of the writer, suitable for use on the 1:250,000 general purpose map. The selection of this method of landform portrayal was based upon a study of the functions of the 1:250,000 map and an examination of several related problems of cartographic design. The suitability of the methods of terrain representation discussed in the preceding chapter was investigated. The Robinson-Thrower technique of pictorial representation was selected.

Function of the 1:250,000 Map

The 1:250,000 Canadian topographic map is a general purpose map. The form and the type of information presented should be suitable for a wide range of users. Marschner has examined some of the functions of these general purpose maps.[1] Topographic maps serve as a record of the local topographical setting and as a starting point for all studies which have the quality and quantity of land as an important consideration. The maps are used as a basis for measurement of land areas and the areal extent of particular phenomena. The topographic map can be used as a base map upon

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[1] F. J. Marschner, "Maps and a Mapping Program for the United States", A.A.A.G., Vol. 33, 1943, p. 213.

which data can be displayed to obtain additional information of location, extent and correlations with other phenomena. The general purpose map provides information on the gross physical and cultural characteristics of an area, and serves as a base map from which other maps may be derived. The topographic map is frequently used in field studies. The portrayal of the terrain serves an important function in all of these areas of use.

The configuration of the surface is a consideration in a wide range of studies. In research on geographic, social and economic studies consideration of the areal extent and occurence of natural phenomena often forms an important part of the study. These elements necessarily have to be mapped in their place of occurrence in order to trace their relationships and to apprehend the natural environment. This is essential whether the study is conducted at a local regional or a national scale. The configuration of the terrain as the most stable element in the landscape exerts a strong influence on land use, and has multilateral relationships with climate, soils and vegetation.[2]

The 1:250,000 topographic map should be designed to function as a general purpose map of the terrain. The method of terrain representation used will

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[2] J. C. Sherman, "Terrain Representation and Map Function", International Yearbook of Cartography, Vol. 4, 1964, pp. 20 - 23.

affect the utility of the map for this purpose. The terms of the description of the land surface must be such that the map can be used as a source of basic topographic information for a wide range of studies.

Canadian topographic maps are published at scales of 1:25,000, 1:50,000, 1:250,000, 1:500,000 and 1:1,000,000. There is some specialization in the uses of these maps according to scale. Studies of limited areal extent which require a finely detailed description of the terrain are best carried out with the aid of the largest scale maps. Research on slope development and measurement, or the evaluation of sites for construction purposes would fall into this category. Topographic maps of scale 1:250,000 and larger can be used to portray broad regional distributions and are used as the base maps for aeronautical charts. The differentiation in function should be taken into consideration in the design of terrain representation for topographic maps at different scales.

At present the method of terrain representation used on the 1:250,000 map is similar to the method used on the 1:25,000 and 1:50,000 maps. Although the contour technique is employed at all three scales, the representation on the 1:250,000 map is necessarily more generalized. At the smaller scale a feature one mile long and 500 feet wide occupies a space on the map measuring only .25 inches by .025 inches. Studies of the detail of the landscape requiring measurement and

identification of small but relevant features must be carried out with the aid of larger scale maps. The contour technique used at the scale of 1:250,000 is a poor guide to the interpretation of the surface configuration. Information surveyed at scales of 1:50,000 and larger is often summarized and transferred to a base map at smaller scale for presentation. In the same manner topographic information mapped in detail at the larger scale should be summarized on the 1:250,000 map.

The function of the terrain representation on the 1:250,000 map should be to provide a summary description of the surface form. The larger features, the variations in the pattern of the terrain, and the characteristics of the form of the land should be presented so that the map reader is provided with a useful image of the landscape.

Selection of the Method of Terrain Representation

The techniques of terrain representation can be classified as quantitative or qualitative methods according to the type of information which is provided on the map.

The uses of the 1:50,000 map are such that the symbolization should be designed to allow the extraction of detailed quantitative information of slope, elevation and relief. The contour is most suitable for this purpose. At a scale of 1:50,000 the contour can be used to determine variations in slope, local relief and elevation. These are the main terms of

description of the geometry of surface form. When the contours are combined with form shading a visually effective portrayal of the surface configuration can be produced. At smaller scales the satisfactory combination of the quantitative technique with a visually effective approach is not so easily obtained. The contour intervals used on the 1:250,000 map are 100 feet, 200 feet, and 500 feet. No accurate indication of slope or local relief can be determined from these maps, and the contours indicate only approximate elevation. Other techniques which could be employed to construct a quantitative description of the terrain at the 1:250,000 scale are generally the least effective visually. A choice must be made between the descriptive techniques employing visually effective symbolization, and those methods which describe the surface in quantitative terms.

Other factors to be considered in the selection of a method of terrain representation for the 1:250,000 map include the utility of the technique as a means of summarizing the characteristics of the terrain, the objectivity of the portrayal, and the suitability of the symbolization for use on a base map.

In the compilation of thematic maps where generalization of a particular subject is required it is possible and often desireable to emphasize certain characteristics of the phenomenon, and to omit others.

The 1:250,000 map intended as a general purpose map cannot be tailored to meet the needs of a particular study. The use of landform categories, or the assignation of emphasis to selected aspects of surface form restricts the utility of the map. Such techniques can be criticized for presenting an over-generalized description of surface form. The slope and relief categories used for some morphometric techniques may be relevant in some conditions and irrelevant in others. The function of the terrain representation is to portray the form of the land as it varies in character from place to place. This is best accomplished if the unity of the phenomenon is retained. Although it is necessary to reduce the geometry of the surface configuration to its component parts for analysis and quantitative mapping the terrain can be treated as a unity where effective visually evocative symbolization is employed. The scale of the presentation on the 1:250,000 map is to small for detailed landform analysis. Effort should therefore be directed towards an effective descriptive map of variations in surface form using any suitable method. The description does not need to be expressed in quantitative terms.

The use of the 1:250,000 map as a base map imposes several design limitations. The symbolization of the terrain should be compatible with overlay or overprinted information. For example, chorochromatic

symbolization of vegetation overprinted on a chorochromatic map of the terrain would produce a map which would be visually confusing and difficult to read. The result would be the same in any case where the systems of symbolization used are the same. The terrain symbolization should be easily interpreted complimentary with other information on the map.

It is the opinion of the writer that the pictorial techniques are most suitable for use on the 1:250,000 map. The morphometric methods based on the mapping of elements of surface form and utilizing linear and areal symbols are inadequate for the objective summary description of shape. Where the quantitative approach is used, the map reader must interpret and reconstruct a mental image of the form of the land. As this image would be based upon the generalized cartographic display of selected aspects of the terrain, the interpretation would vary according to the familiarity of the reader with the technique used, and the parameters employed. Several available pictorial techniques facilitate the mapping of form directly using visually evocative symbols. The image so produced is designed for visual interpretation and is therefore easily read. This morphographic approach permits the cartographic reconstruction of an edited version of the appearance of the terrain.

Pictorial techniques are not designed for detailed quantitative measurement. This is not a

requirement of the 1:250,000 map. The local relief can be measured approximately where the proportional relief method is used. Some quantitative information can be provided by the addition of contours, spot heights, or hypsometric tints where other techniques are used.

Of the several morphographic techniques studied, three were considered for possible use on the experimental map. These are the proportional relief method,[3] the "Swiss method" combining contours, form shading, altitude tints and rock drawing, and the method employing orthogonal traces of the inclined plane developed by Robinson and Thrower.[4] The proportional relief method was discarded because planimetric displacement of points, although reduced, is necessary in the construction of the symbols. The effective use of form shading for the cartographic description of mountain areas has been demonstrated on a variety of topographic sheets. The Swiss topographic maps are particularily noted in this respect. The Robinson-Thrower technique has been applied experimentally at large scales but is not in general use. The two methods are compared in figure ten.

The Robinson-Thrower technique was selected for use on the 1:250,000 map. The choice was based on several considerations. The line drawing technique is

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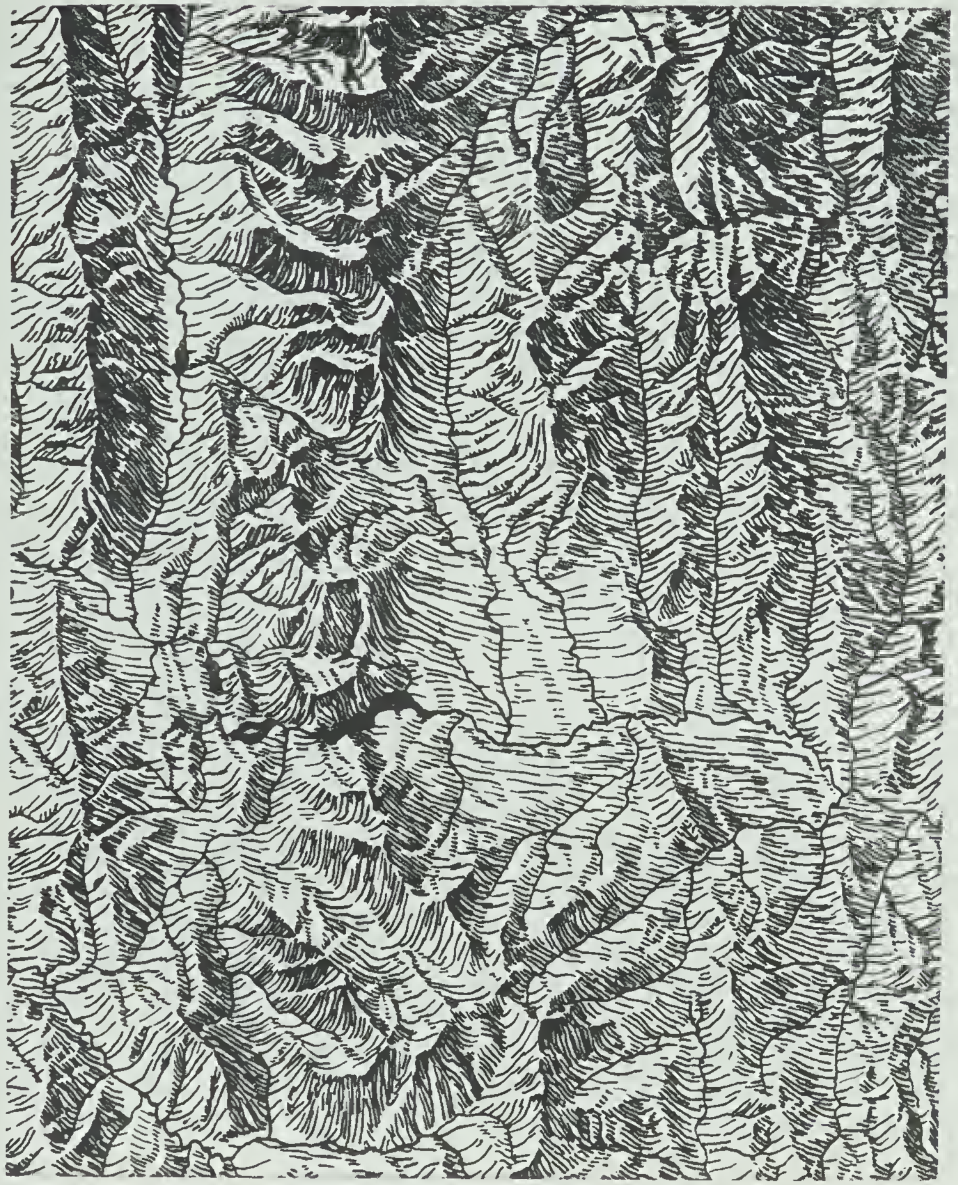
[3] M. K. Ridd, "The Proportional Relief Landform Map", A.A.A.G., Vol. 53, 1963, p. 569.

[4] A. H. Robinson and N. J. Thrower, "A New Method of Terrain Representation", Geogr. Rev., Vol. 47, 1957, pp. 507 - 520.



Pictorial Terrain Representation, Drawn According to the Method Described by A.H.Robinson and N.J.W.Thrower

Form Shading and Contours (Contour V.I. 500')

FIGURE 10 A COMPARISON OF TWO METHODS OF TERRAIN REPRESENTATION AS APPLIED TO THE SAME AREA

THE AREA IS A PART OF THE CROWSNEST PASS. SCALE 1:250,000

more flexible than shading for the rendering of fine detail. By varying the density of the lines drawn on opposing slopes contrasts of light and shadow can be created as with form shading. The Robinson-Thrower technique provides an additional method of defining detail, the inclined contour. Variations of height and slope represented by the length and darkness of the shading are difficult to interpret on maps where form shading is employed alone. This characteristic of the method is brought out in figure six, a reproduction of a section of the ESU N.W. sheet produced at a scale of 1:50,000 for the Nigerian government. The problem can be overcome by using contours with the shading. Relative heights of features, lengths and steepness of slopes can be indicated on the map by the traces of the inclined plane where the Robinson-Thrower technique is employed. There are limitations, however, to the effectiveness of the slope portrayal. A good qualitative judgment can be obtained only where the direction of slope is parallel to the horizontal lines. The apparent displacement does provide a basis for the interpretation of the relative relief of features, lacking where form shading is employed. The control provided by the framework of traces is an aid to the elimination of inconsistency in the application of pictorial symbolization, a problem recurrent in the application of form shading.

The technique of form shading is well known and frequently used for a variety of maps. The Robinson-Thrower

technique is, in contrast, not used on topographic maps. It is apparent that form shading can be applied successfully at a scale of 1:250,000 and the technique is satisfactory for most of the requirements of the map. The author was interested in examining the results of the application of the Robinson-Thrower method, a technique which appeared to be as suitable and in several ways superior to the form shading approach. The infrequent use of the orthogonal traces of the inclined plane to construct pictorial terrain rendering for general purpose maps was a final consideration which contributed to the choice of this technique.

CHAPTER IV

THE EXPERIMENTAL MAP

An experimental map of a part of southwestern Alberta was prepared at a scale of 1:250,000. A variety of terrain within the map area served as a test of the application of the Robinson-Thrower technique[1] to diverse land forms. An investigation of the general physiography and geology of the area was carried out. This study was of assistance for the interpretation of features and served as a guide to the selection of forms for emphasis during the construction of the pictorial representation. The symbolization of the terrain was constructed in the manner described by Robinson.[2] Spot heights, selected place names, and hydrography were added. The map, reproduced monochromatically by photographic means, presents an effective and useful portrayal of the surface form of the area.

The Map Area

The map area includes parts of the 1:250,000 topographic sheets, 82G, 82H, 82I and 82J. This is a section of southwestern Alberta and an adjacent part of British Columbia extending from 113° W. Long. to 115° W. Long and from 49° 30' N. Lat. to 50° 30' N. Lat.

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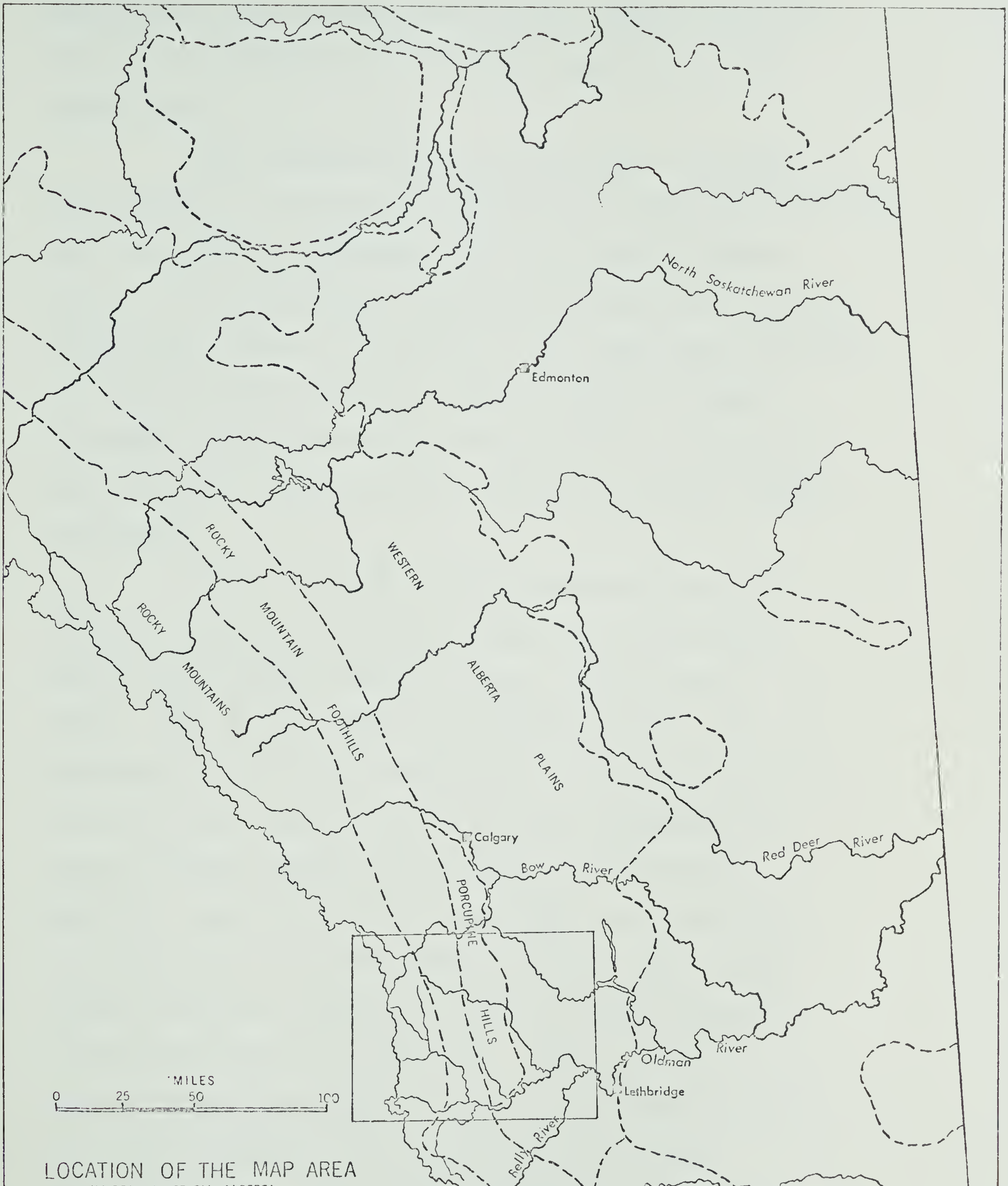
[1] A. H. Robinson and N. J. W. Thrower, "A New Method of Terrain Representation", Geogr. Rev., Vol. 47, 1957, pp. 507 - 520.

[2] Ibid.

The location of the area is shown in figure eleven. The area was chosen as the subject for the experimental map on the basis of its varied topography. Within this comparatively small area are portions of four major physiographic units. These include, the Western Alberta High Plain, the Porcupine Hills, the Rocky Mountain Foothills and the Rocky Mountains. Running north-south near the centre of the map area is a major boundary of the geologic structure. The hills and plains to the east are underlain by a broad syncline, and belong to the Interior Plains physiographic region. The foothills and mountains to the west of this boundary are formed upon complexly folded and faulted strata and belong to the larger Western Cordillera physiographic region. The several topographic units of the map area are a reflection of the underlying structure as modified by stream erosion, glaciation and weathering.

General Physiography and Geology of the Map Area

The information for the following survey was taken from a variety of sources. These included topographic maps, and published memoirs, bulletins, reports and maps of the Geological Survey of Canada, and the Research Council of Alberta. The scope of the study was quite limited. The writer was concerned with the representation of the characteristic features of the area rather than the analysis of the physiography. The features discussed here are those which were



LOCATION OF THE MAP AREA
IN SOUTHWESTERN ALBERTA
FIGURE 11

emphasized in the construction of the terrain symbolization in an attempt to reproduce the appearance of the surface form.

The Porcupine Hills and the area of plains and uplands to the east are underlain by the same structural unit, the Alberta syncline. This is a broad feature formed of gently eastward dipping Cretaceous and Tertiary sedimentary rocks. The surface strata have been subjected to stream erosion leaving remnant uplands, the most prominent of which are the Porcupine Hills. Subsequent glaciation has removed much of the detail of the bedrock topography.

The west front of the Porcupine Hills lies along the line of the valley occupied by the Oldman River, Callum Creek, Swanson Creek, and the Chain Lakes. This valley marks the boundary between the disturbed belt of the foothills and the Alberta syncline. The west face of the hills is a cuesta underlain by strata dipping eastward at fifteen to twenty-five degrees. Lack of laterally persistent and resistant rocks results in a poorly defined crest. The cuesta is best developed along the central portion where it reaches elevations of 5,900 feet. There the west flowing streams are shorter than to the north and south where penetration of the hills produces a deeply crenulated front. The strata exposed on the eastern face of the hills have a slight westward dip, indicating

that the synclinal axis runs north through the hills. The syncline plunges to the north where its surface expression is more subdued.

The Porcupine Hills are a remnant of a previous erosion surface. The topography has the appearance of a stream dissected plain in early maturity. The valleys are wide and well developed. Floodplains and interfluves are relatively small, the largest part of the area taken up by valley slopes. The flat summit areas and horizontal outcrops along the slopes reflect the underlying structure. There is a pronounced break in slope where the hills meet the lowlands on the east and to the south. To the north the differentiation of hill and plain is less distinct, a consequence of the northerly plunge of the geologic structure. Relief varies. The highest elevations, in excess of 5,900 feet are reached along the crest line of the central part of the western cuesta. Local relief is between 1,000 and 2,000 feet in that part of the hills. Elevations and local relief generally decrease to the east and to the north where the hills merge with the plains. On Bullock's map of southern Alberta[3] the largest part of the area is shown to have modal slope values of between twenty and fifty per cent. These occur in the areas

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[3] M. A. Bullock, "A Landform Map of Southern Alberta", unpublished M. Sc. thesis, University of Alberta, 1966, accompanying map.

where local relief exceeds 600 feet. The northeastern third of the hills is shown as having a local relief of between 300 and 600 feet. Slopes in this area are generally gentler.

The topography of the plains area varies from flat to gently rolling. Steeper slopes and rough ground are found along incised river valleys, in areas of extensive gulleying and where hummocky ground moraine has been deposited. In Tertiary time weathering and stream erosion had produced a more mature topography of broad valleys, well defined drainage divides, and low rounded uplands. The effect of glaciation was to "smooth out" the surface. Preglacial valleys were filled with glacial deposits, and minor irregularities obliterated by a mantle of till varying in thickness up to 200 feet.[4] The average thickness of the till is about fifteen feet.[5] The present youthful drainage has cut into these unconsolidated deposits and only in sections of the deeper river valleys is bedrock erosion currently taking place.

There are several upland areas to the northeast and along the southern boundary of the map area. These erosional remnants mark the drainage divides of

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[4] K. W. Geiger, Bedrock Topography of Southwestern Alberta, Research Council of Alberta, Preliminary Report, No. 65-1, 1965, accompanying map fig. 2.

[5] Geological Survey of Canada, Surficial Geology High River, Map 14 - 1957.

the preglacial topography. Wild Turnip Hill, the rise southwest of Fort Macleod, and the upland areas around the Thigh Hills are characterized by long gentle slopes and elevations 300 to 500 feet higher than the adjacent plains.

Extending through the central part of the plains area is a lowland characterized by extensive flats, poorly developed drainage and slight relief. The incised valleys of the Oldman River, the Belly River, and the Little Bow River are the most prominent topographic features of this area. The Belly River flows in a broad preglacial valley between two upland areas. It is deeply incised only along its lower course where it joins the Oldman River. Flowing east from the foothills, the Oldman River is entrenched in a narrow valley across the southern slopes of the Porcupine Hills. The valley sides are severely gulleyed in several places in this area. Alluvial terraces are prominent where the tributaries enter the river. Beyond the Porcupine Hills the Oldman River passes through an area of topography modified by lake erosion and deposition. There the valley is less pronounced. Near the junction with the Belly River, the valley is better defined and the river flows 200 feet below the level of the adjacent plain. The valley of the Little Bow River changes in character along its course. Upstream the river runs in a wide box-shaped channel of low relief. To the south and east

the banks are higher and the river flows through a series of entrenched meanders. The depth of the valley in this area does not generally exceed 200 feet. The three main rivers have very few tributaries in the plains area. The entry point of streams entering the main channel is often characterized by steep-sided ravines which may extend several hundred yards to several miles along the tributary.

Much of the detail of the terrain was formed by glacial deposition and erosion during the Wisconsin glaciation. To the north and along the eastern face of the Porcupine Hills there are a series of meltwater channels. These were formed by runoff from the melting ice in the foothills and mountains to the west. Temporary streams running south along the face of the Laurentide ice sheet cut a series of short but quite pronounced channels through the ridges and high lands of the Porcupine Hills. Many of these valleys are between 100 and 300 feet deep.[6] In the plains area the channels are longer but not as pronounced. There are several small areas of hummocky moraine. The most prominent of these are south of the Oldman River near the southern margin of the map area. Trending south-east from the junction of the Little Bow River and Mosquito Creek is a belt of eskerine deposits which is

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[6] Ibid.

a prominent feature in the appearance of the terrain in that area. The surface expression of the glacial deposits over much of the plains area is either nondescript or of very low relief. The extensive areas of ground moraine and lacustrine deposits, and the minor features of the washboard moraines, flutings and eskers can be included in that category. Although the surficial geology of the area was noted during the compilation of the map[7] only the more pronounced features discussed above could be represented.

The mountains and foothills occupying the western part of the map area are the product of relatively recent (Tertiary) tectonic activity. The uplift of the Rocky Mountains was accompanied by great pressure from the west. The previously horizontal sedimentary rocks of the RockyMountain geosyncline were folded and fractured along less competent beds. Increased pressure in Eocene time was released in a series of great overthrusts. The most notable of these, the Lewis thrust, brought the front of the main ranges much closer to the margin of the disturbed belt in southern Alberta. For this reason the foothills belt, and the front ranges are much narrower in this area, than farther north. Three units of the mountain region can be recognized in the map area.

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[7] The surficial geology of the area is described on the Geological Survey of Canada Maps 21 - 1956, 14 - 1957 and 31 - 1961.

These are, from east to west, the foothills, the Front Ranges, and the Main ranges. A fourth subdivision of lower mountains can be defined between the Livingstone-Highwood ranges, and the High Rock - Elk Ranges.

Generally the structure of the mountains and foothills is characterized by folding and thrust faulting along a regional north trending strike. The foothills belt is underlain by frequent minor thrusts producing an imbricate structure of overlapping strata, and the repeated exposure of the same Cretaceous sandstones and shales. To the west, the scale of faulting increases and older more resistant strata have been brought to the surface. The Livingstone Range was produced by a massive overthrust of Mississipian and Devonian limestones. The fault line can be traced along the front of the steeper, east facing, strike slope, north. Between the Livingstone Range and the main mountain ranges softer Mesozoic sandstones and shales have been exposed. These have been subjected to complex folding and faulting in contrast to the simpler, more massive structures of the ranges to the west. The High Rock Range marks the front of the great Lewis overthrust of Eocene time. Harder Mississipian and Devonian limestones have been thrust from the west over the later Cretaceous sandstones to form an impressive mountain front. The fault line can be traced north along the east slope of the range.

The topography of the foothills is characterized by a series of north trending ridges which are frequently cut by east flowing streams. The less resistant shales and weak zones of shattered rock along the fault lines have been carved by stream erosion, forming valleys between the harder sandstones. The entire foothills belt was overrun by piedmont glaciers which rounded the sandstone ridges and widened the valleys. Morainic terrain and outwash deposits are found on the valley floors and lower slopes. The topography is of moderate local relief, varying from 500 feet to 1,500 feet. The foothills belt widens from eight miles in the south to twenty miles in the north.

The Highwood Range and the Livingstone Range are the front ranges of the mountain belt in this area. The Livingstone Range is a narrow north-south lineament formed from overthrust Paleozoic limestones along the line of the Livingstone fault. The structure plunges to the south below the Crowsnest River. To the north the range is cut frequently by streams flowing west from the foothills. Maximum elevation reached is 8,400 feet. South of the Oldman River the range is characterized by sharp summits and cirques developed above 7,500 feet. To the north the summit areas are broader and more rounded. Plateau Mountain at the north end of the range is characterized by relatively steep lower slopes, and a broad flat summit area formed on the horizontal

underlying limestones.

The Highwood Range has been deeply dissected by glaciation, and is characterized by high steep cliffs and rugged sharp crested ridges. Mount Head, reaching an elevation of 9,126 feet is the high point of the front ranges in the map area. South of the Highwood River the range is composed of three lower strike ridges. These ridges merge and elevation increases to the south.

Between the front ranges and the High Rock and Elk Ranges elevations are generally lower. The lithology and structure are similar to that of the Foothills area. The underlying rocks are tilted Mesozoic shales and sandstones, less resistant to weathering and erosion than the limestones of the ranges to the east and west. The width of this belt of lower mountains varies from six to eight miles in the north to fifteen miles in the south. The belt is cut by many second and third order streams flowing transverse to the regional strike. Their smaller tributaries have developed valleys along the north trending lines of lithologic and structural weakness. The north trend of the interfluvial ridges is apparent but not so pronounced as in the foothills and front ranges to the east. Many of the larger valleys exhibit the U-shaped form resulting from glacial erosion.

The High Rock and Elk Ranges present a wall of high steep sloped glaciated mountains marking the front

of the main ranges of the Cordillera. The east face of the ranges marks the limit of the Lewis overthrust of Paleozoic limestones. Mountain glaciers formed on the upper slopes have carved a rugged summit area of sharp crests and steep cliffs. Many of the landforms of alpine glaciation, cirques, cols, arêtes and horns can be detected here. Moving downslope the coalescing glaciers widened and smoothed the slopes of the stream eroded valleys. Particularly prominent to the west is the wide U-shaped valley of the Elk River.

Compilation of the Experimental Map

The procedure for the construction of the orthogonal traces of the inclined plane, as described by Robinson[8] is summarized below. The traces are constructed on a contour base map of a given scale. The base map is covered with a network of parallel, equispaced, horizontal lines. These lines perform a dual function. They define the line of intersection between each inclined plane and the plane of the map. The spacing of the lines is calculated so that each line can be used to determine the point of contact between successive contour elevations and the inclined plane. The intersection of the lowest contour and the lowest horizontal line is connected by a smooth line with the intersection of the next higher contour and

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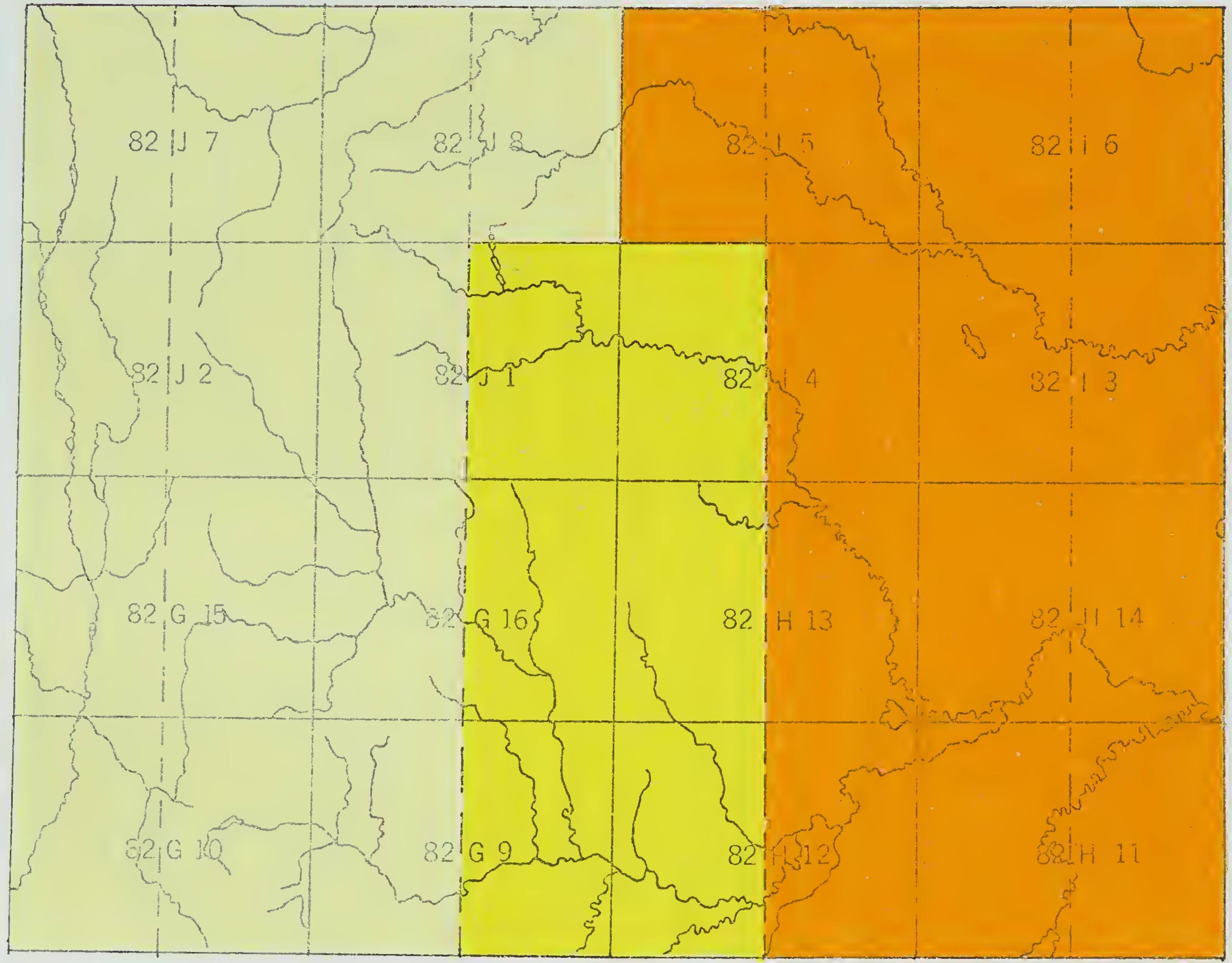
[8] Robinson, *op. cit.*

next horizontal line, and so on. The resulting trace is similar in appearance to a profile. This is the orthogonally projected trace of the inclined plane. The procedure is repeated for each horizontal line until the map is covered by a succession of these traces. The traces are then used to construct the pictorial terrain symbolization.

The apparent vertical exaggeration of the terrain will be governed by the angle of inclination of the planes used. The higher this angle, the "flatter" the terrain will appear. The trace of a plane angled at 90° to the surface is a profile which when projected orthogonally onto the map would appear as a straight line. Where the angle equals 0° the planes are horizontal to the map surface and the traces are contours. Robinson suggests the use of a value which lies in the middle range of possibilities.

The calculation of the spacing of the horizontal lines is based upon the value of the angle of inclination selected, the vertical interval of the contours used, and the scale of the map. The formula used is $D = \frac{12\ h \cot \theta}{S}$ where D is the spacing of the horizontal lines, h the contour interval expressed in feet, and s, the scale denominator of the map. This formula permits the spacing of the lines so that one set of parallel lines represents the contours of all the inclined planes. The lower the value used for θ, the larger the interval between the



1:50000 SCALE CANADIAN TOPOGRAPHIC SHEETS COVERING THE AREA OF THE EXPERIMENTAL MAP

FIGURE 12

NTS INDEX NUMBERS 82 G 10

CONTOUR INTERVALS ON INDIVIDUAL SHEETS 25 50 100

parellel lines, and the apparent displacement of features will be greater.

The contours used on the base map for the compilation of the experimental map were taken from the relevant sections of the 1:250,000 Canadian topographic sheets covering the area. The contour interval used on the sheets covering the western part of the area (82J and 82G) is five hundred feet, the contour interval of the eastern sheets (82I and 82H) in one hundred feet up to an elevation of five thousand feet, and two hundred feet above. The contour interval used for the calculation of the spacing of the horizontal lines was five hundred feet. Preliminary experimentation with the formula indicated that the use of a smaller contour interval would result in a network of lines too closely spaced for convenient symbol construction. Contours were available at five hundred foot intervals for the whole area excluding a small section of the Porcupine Hills. The maps used are indicated in figure twelve.

The value for θ used was 25°. This is smaller than suggested by Robinson. There are several reasons for the selection of a low angle of inclination. Comparative maps of the traces of the terrain of a small area were drawn using values for θ of 20°, 25°, 30° and 45°. The variation of the apparent vertical exaggeration of features with variation in the value

of the angle of inclination is illustrated in figures thirteen, fourteen, fifteen and sixteen. The figures are drawn at twice the compilation scale of 1:250,000 for clarity. The amount of vertical exaggeration required to bring out the profile of surface features is to some extent a function of scale. At smaller scales a greater vertical exaggeration should be used. This is necessary because the ratio of vertical relief to horizontal distance is usually small and decreases with reduction of scale. An apparent vertical displacement of five hundred feet measures only .024 inches at a scale of 1:250,000. At a scale of 1:50,000 the displacement is .12 inches. Such variations at the smaller scale have little meaning. At the smaller scales more generalization of shape of features is necessary. Breaks in slope defining stream beds and hillocks must be omitted and long slopes appear smoother than at larger scale. The irregularities of the terrain are less pronounced. The flattening effect of the small displacement and the longer smoother slopes reduces the necessary contrast between different types of terrain. Local relief varies considerably over the map area. It is possible to select a value for the angle of inclination which is suitable for the representation of the mountain areas but unsuitable for the portrayal of the moderate relief of the hill areas.

The angle of inclination selected resulted in

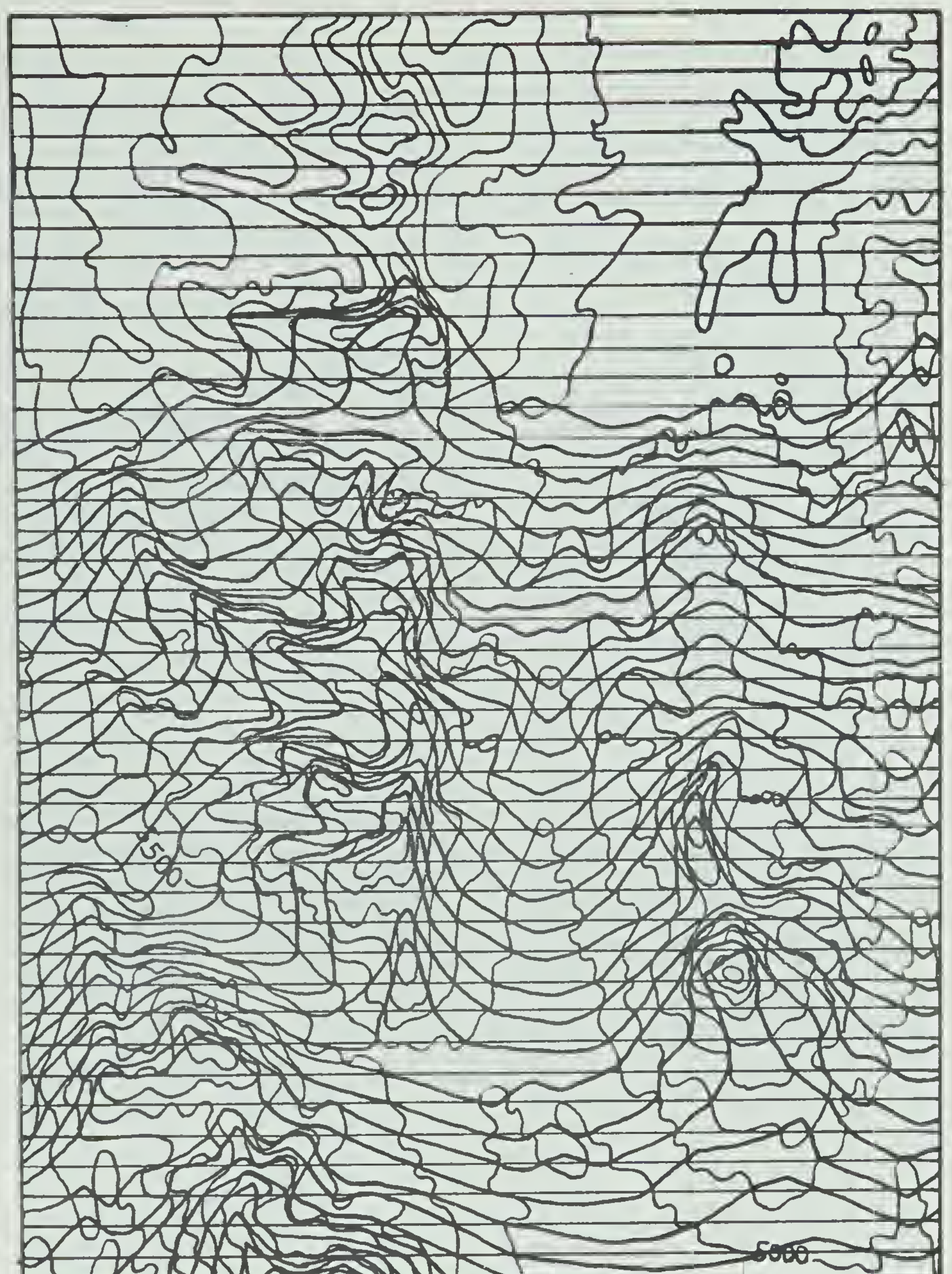


FIGURE 13 TRACES OF THE INCLINED PLANES, ANGLE OF INCLINATION 20°

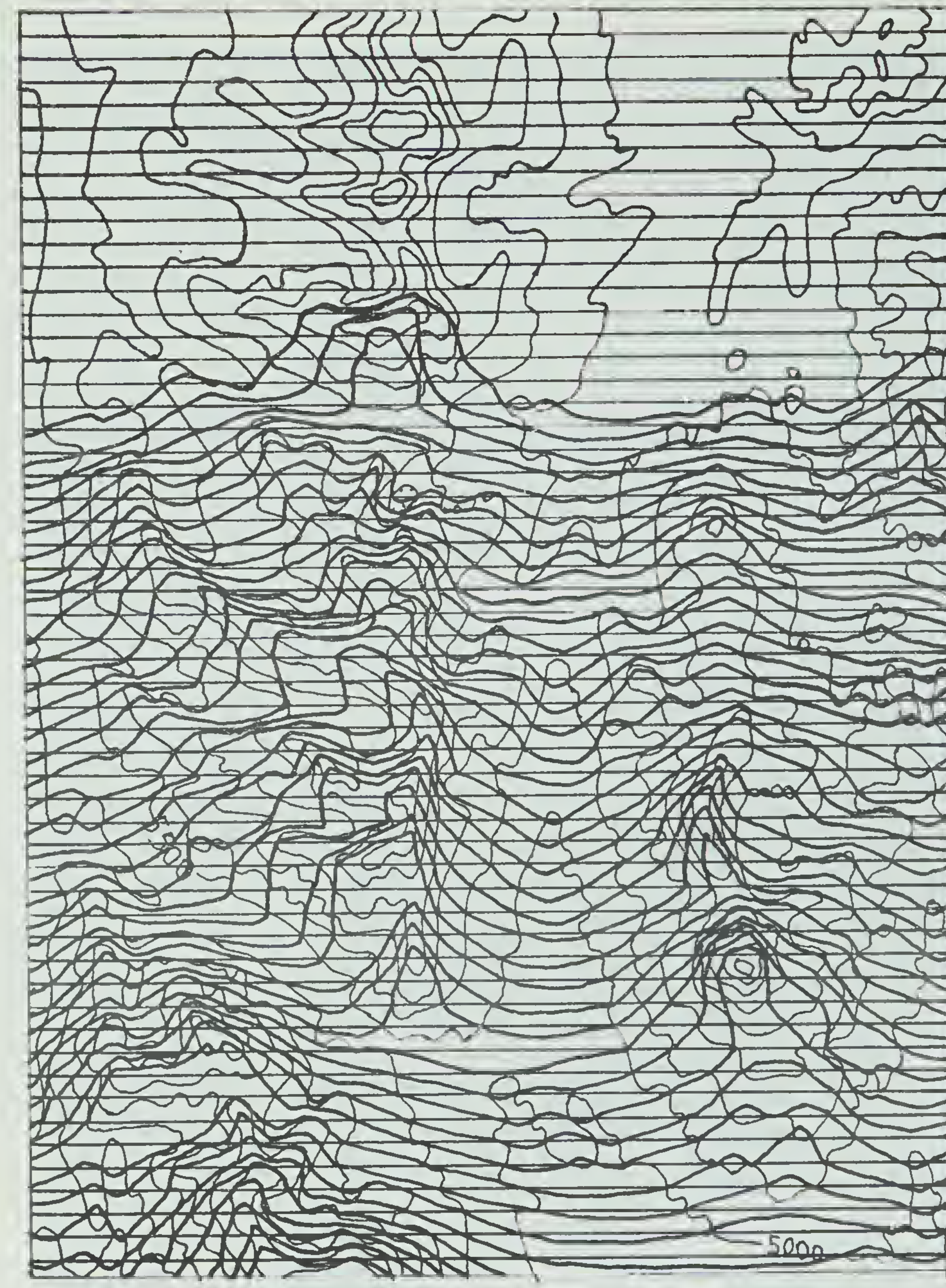


FIGURE 14 TRACES OF THE INCLINED PLANES, ANGLE OF INCLINATION 25°

a greater exaggeration of the mountains than necessary in order that the hill features of the central part of the map area might be better shown.

A second consideration of importance in the choice of the value for θ was the convenience of the spacing of the traces for use in pictorial terrain rendering. The more closely spaced lines of figure sixteen for which a value of 45° was used for θ, are more suggestive of the surface form than the traces of the other three figures, thirteen, fourteen and fifteen. The lines are spaced at intervals of .024 inches where θ equals 45°, and only .065 inches where θ is equal to 20°. The smaller features defined by one or two traces where the lower value is used, are defined by three to six traces where the angle of inclination is 45°. The smaller angle does not provide sufficient indication of surface form for use in the construction of the terrain symbolization. Where θ equals 25° the spacing is .05 inches. This value was judged to be most suitable, providing sufficient vertical exaggeration and yet retaining detail in the moderately close spacing.

The traces were drawn by joining the intersections of lines and contours with smooth lines. The surface represented by the traces reflects the generalized contours of the 1:250,000 map. Many of the features of limited extent or moderately low relief which can be

shown by pictorial means were not defined by the traces. In addition the traces were constructed only for the western two thirds of the map area. To the east relief is too low, and the slopes of the rises too long to be usefully treated in the manner. The traces were used only as guides indicating the general shape and direction of slopes for the larger features. The technique suggested by Robinson for the terrain rendering is based upon the interpolation of additional "profile" lines between the traces. A larger number of traces and interpolated lines are used on the "dark side" of the feature than on the light side to achieve a shaded effect. In practice the terrain drawing requires considerable interpretation and modification of the outlines defined by the traces.

The 1:50,000 topographic sheets of the area were used as the primary source of information for the terrain drawing. The features were located on the base map. The outline of the shape was checked against the large scale map. Each feature was drawn as interpreted from the 1:50,000 maps, within the framework provided by the traces. The eastern part of the map area, not covered by the traces was checked against the large scale maps. River valleys, hummocky terrain, and upland areas which are of importance in the appearance of the terrain were drawn in pictorially. There are no areas of local relief exceeding 500 feet in this

part of the map area.

Although air photographs are available for most of the area, the information provided by the 1:50,000 maps was sufficient for the terrain drawing. The contour interval of the large scale maps ranges from twenty-five feet in the east to one hundred feet in the west. The vertical interval is small enough to indicate features which can be shown at a scale of 1:250,000.

The terrain rendering was drawn in ink on a plastic overlay placed over the base map. Initially some difficulty was experienced in developing a consistant graphically descriptive technique of symbolization. Robinson states that:

> "One of the problems inherent in drawing landforms is that position, shape, and size relationships are usually exceedingly complex. The geographer frequently finds himself unable to comprehend clearly the broader, three dimensional form relationships that exist on the earth's surface. Or he may be aware of them but has not the skill to arrange them graphically, so that they appear to fit together. The artist on the other hand, learns to perceive and delineate such relationships.[9]

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[9] Robinson, <u>op. cit.</u>, p. 510.

The traces are designed to be used to provide much of the unity characteristic of the artist's rendering. Furthermore, it was intended that by means of the inclined contours the relationships of the various features could be more rigorously controlled. During the construction of the terrain drawing the traces were found to be useful to the extent that they provided a control of size relationships. The effectiveness of the graphic symbols for suggesting volume, shape, and detail of the surface was to a great extent dependent upon the use of artistic interpretation and techniques. Consequently it is suggested that should several maps of the same area be prepared by different persons, significant variation in the detail and visual impact of the drawing would result.

Although the pictorial symbolization gives a good idea of relative heights of features it was considered desirable to provide a scale of absolute values for judging relief. Contours cannot be effectively used on the background provided by the line drawing. Hypsometric tints could be used but the desirability of maintaining the monochromatic background for use on base maps, and the difficulties of reproduction precluded their use. Spot heights were used. The elevations were selected from those used on the 1:250,000 sheets. Where spot heights were not provided the approximate elevation was calculated from the 1:50,000 contour maps.

Elevations were chosen to give an indication of the variation of both summit levels and base levels over the area. Spot heights were placed at intervals along river valley floors to give an approximate indication of the drop in slope and thereby permit interpolation of elevations along the valley bottom. In the hill and mountain areas local high points and prominent features were selected. An approximate evaluation of local relief can thereby be made from the map. The heights are intended, however, only as a guide in the interpretation of the pictorial terrain symbolization.

No distinction is made in the character of the lines representing permanent and intermittent streams. The conventional dashed or dotted line used to symbolize intermittent drainage lacks clarity when used on a background of line symbols. All stream drainage shown on the 1:250,000 topographic maps is symbolized on the experimental map by means of solid lines. A distinction is made between permanent lakes, in solid black, and temporary lakes, shown in outline by dotted lines. The use of conventional symbols would be appropriate where reproduction in several colours.

Place names, names of physical features, roads, railroads, town symbols and spot heights were drafted on a separate plastic overlay. This information, with the exception of the spot heights, was

generalized from the 1:250,000 scale topographic sheets. The use of the overlay permitted the separate photographic exposure of the terrain and the other information. This was necessary in order to reduce the tone of the terrain drawing so that names and elevations would be legible on the background. The terrain drawing can be sufficiently lightened for overprinted information to be legible, without losing the definition of surface form.

The writer was concerned with the use of the terrain drawing as an underlay to aid in the presentation of information. Figures seventeen and eighteen illustrate this use. In figure seventeen a part of a morphometric landform map[10] is reproduced on the background formed by the pictorial terrain representation. One drawback of the morphometric approach is that the symbolization is abstract and the terms of description are often unfamiliar. The use of a technique of pictorial description as an underlay can enhance the map readers understanding of the information presented. Although this combination of technique is unsuitable for use on the general purpose map, the effect is useful for thematic treatments of the terrain. The morphometric information was enlarged from a scale of 1:1,000,000 and is therefore more generalized than is required.

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[10] Bullock, _op. cit._

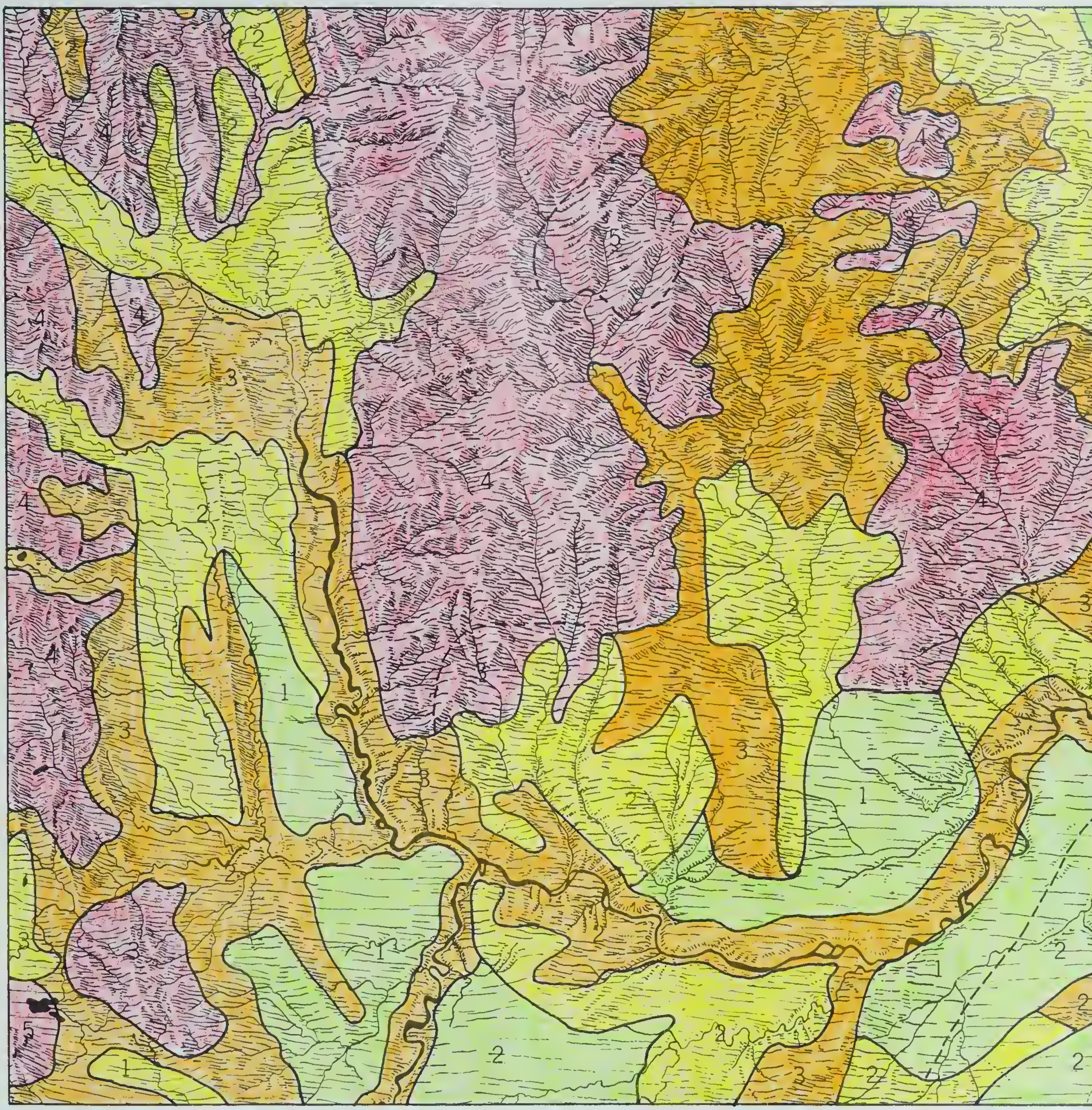

FIGURE 17 A CARTOGRAPHIC REPRESENTATION OF THE LANDFORM OF A PART OF THE MAP AREA, USING A COMBINATION OF QUANTITATIVE AND QUALITATIVE TECHNIQUES (MORPHOMETRIC SLOPE AND RELIEF INFORMATION FROM M.A.BULLOCK, "A LANDFORM MAP OF SOUTHERN ALBERTA")

Slope Class	Limits (Per Cent)
A	0 - 5
B	5 - 10
C	10 - 20
D	20 - 50
E	50 - 100
F	100 - ∞

Relief Class	Limits (Feet per Mile Square)
1	0 - 100
2	100 - 300
3	300 - 600
4	600 - 1,000
5	1,000 - 2,000
6	2,000 - 5,000

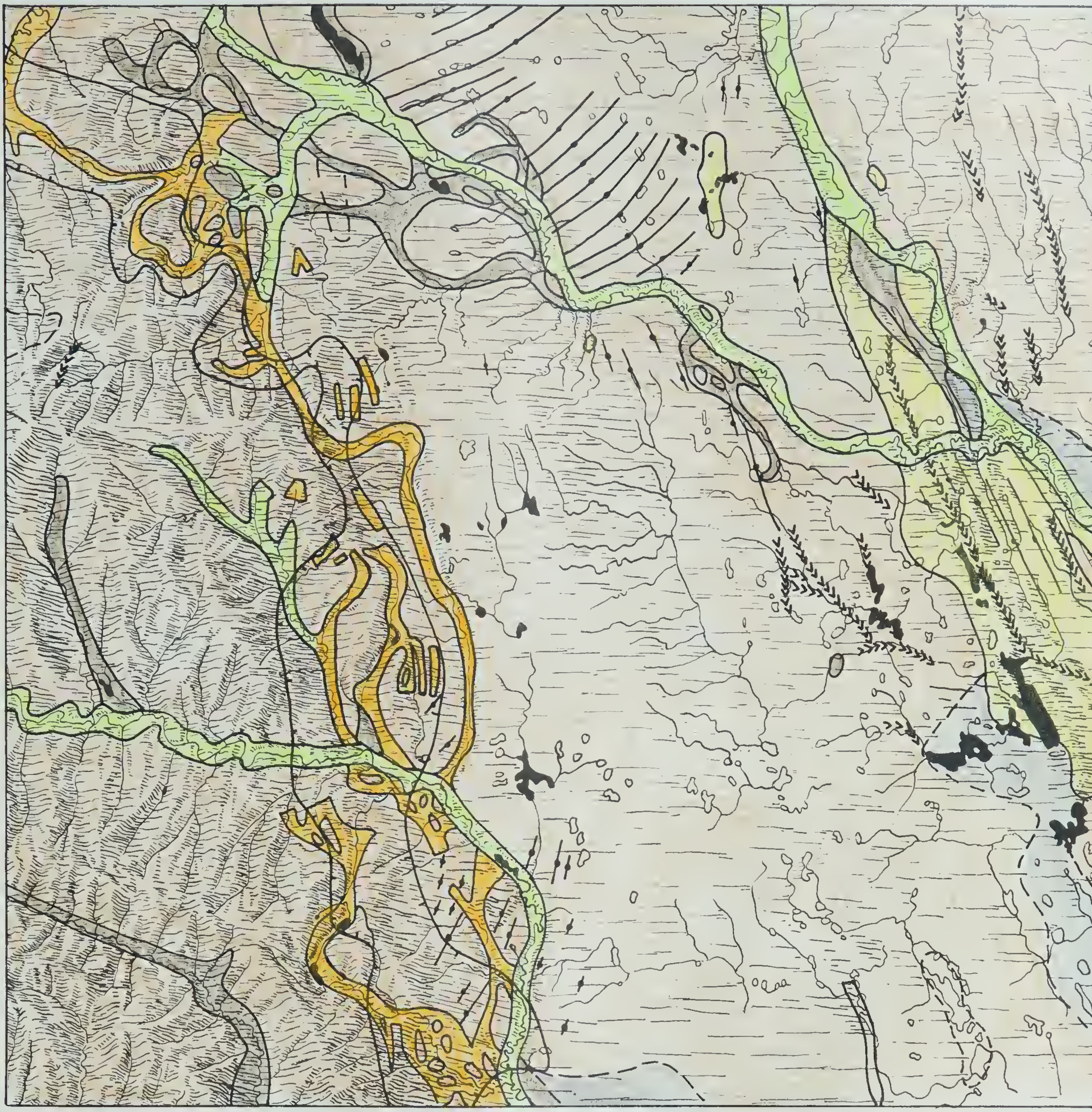

FIGURE 18 GENERALIZED SURFICIAL GEOLOGY OF A PART OF THE AREA OF THE EXPERIMENTAL MAP SOURCE: GEOLOGICAL SURVEY OF CANADA, SURFICIAL GEOLOGY HIGH RIVER, MAP 14-1957.

RECENT

MODERN STREAM DEPOSITS

PLEISTOCENE AND RECENT

LAKE DEPOSITS

PLEISTOCENE

FLOODPLAIN OR DELTA DEPOSITS

OUTWASH AND KAME DEPOSITS

GROUND MORRAINE

PLEISTOCENE

ICE FLOW MARKINGS

ESKER RIDGE

LIMIT OF QUARTZOSE CONGLOMERATE BOULDER TRAIN

CRETACEOUS AND TERTIARY

BEDROCK

For this reason the quantitative description and the pictorial representation do not consistently correspond in the illustration. The information used for figure eighteen is taken from the Geological Survey of Canada Surficial Geology High River, map 14 - 1957. In this example much of the detail of the surficial geology which has expression in characteristic land forms in not indicated on the pictorial map. The illustration provides some indication of the extent of generalization of the 1:250,000 map. Pictorial symbolization forms an effective background for the display of additional information. The approach could be used more frequently not only on topographic maps but also on a wide range of thematic maps.

CONCLUSION

Proper map design and symbolization are as important for the cartographic communication of facts and idea as the data used. The cartographer must avoid the use of techniques which interfere with the easy visual examination of the map. The visual impression derived from the organized display of colour, tone, line and shape can strongly influence the map reader's ability to interpret the map.

The aim of most cartographic design is no more than the construction of a legible map which adequately describes the subject according to the data used. In the opinion of the writer the cartographic method could be used more effectively for some purposes. When the generalization of information is carried to the point where the data no longer serves to adequately describe the subject, the cartographer should use his graphic techniques in an interpretive manner. Symbolization can be used to aid in the description.

The mapping process requires that a number of decisions be made which will influence the character of the information presented on the finished map. The effect of the presentation and the accuracy of the map will vary according to the approach taken by the individual or individuals engaged in the compilation and design. Regarded from this point of view the map appears to be a relatively subjective instrument.

The Robinson-Thrower technique of terrain representation is potentially useful for application to a wide range of mapping problems. That the technique be suggested for use on topographic maps may seem unrealistic when the time and abilities required for its application are considered. Neither of these factors were considered in the selection of the technique. The object of the study was to select the most functional technique from the point of view of content and design.

New techniques of gathering and processing data will undoubtedly have their effect on map design. Consideration should be given to the form in which this information can be most effectively presented. An examination of the potential of remote sensing devices and computerized processing of data was beyond the scope of this study. It is probable that radical changes in terrain mapping will be the result of research in these areas. The time required for the construction of pictorial terrain representation and the degree of interpretation required, which are major drawbacks to the widespread use of this technique, may be reduced.

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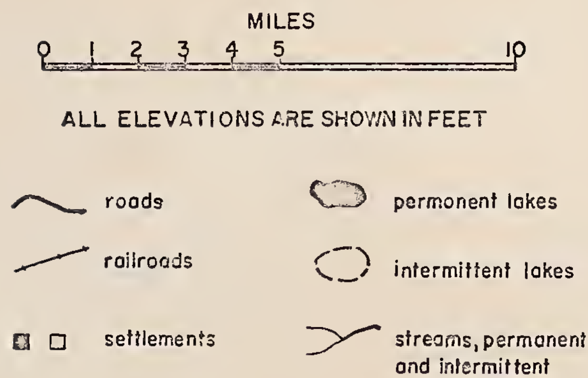
FIGURE 19

A PART OF SOUTHWESTERN ALBERTA

AN ILLUSTRATION OF THE DESCRIPTION OF THE TOPOGRAPHY BY MEANS OF THE ROBINSON-THROWER TECHNIQUE OF PICTORIAL TERRAIN REPRESENTATION

UNIVERSAL TRANSVERSE MERCATOR PROJECTION

SCALE 1:250,000



SOURCES: CANADIAN TOPOGRAPHIC MAP SHEETS 82 G, 82 H, 82 I, 82 J, SCALE 1:250,000, AND MAP SHEETS 82 G 9, 82 G 10, 82 G 15, 82 G 16, 82 H 11, 82 H 12, 82 H 13, 82 H 14, 82 I 3, 82 I 4, 82 I 5, 82 I 6, 82 J 1, 82 J 2, 82 J.7, 82 J 8, SCALE 1:50,000.

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Cayley
Pekisko
Connemara
NANTON
VULCAN
Ensign
Kirkcaldy
Durward
Parkland
Champion
Stavely
Pulteney
CLARESHOLM
Woodhouse
Granum
Carmangay
Peacock
Barons
Nobleford
FORT MACLEOD
Chain Lakes
PORCUPINE HILLS
ELK RIVER
LITTLE BOW RIVER
OLDMAN RIVER
NATAL
MICHEL
COLEMAN
BLAIRMORE
Frank
BELLEVUE
HILLCREST MINES
Lundbreck
Cowley
Pincher Station
Brocket
WILD TURNIP HILL